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The 1990 AMSAT Annual Meeting and Space Symposium

The Johnson Space Center, Houston, Texas

October 19, 20 and 21, 1990

By Bill Tynan, W3XO

The Johnson Space Center (JSC) Amateur Radio Club will host this year's AMSAT-NA Annual Meeting. The site will be the JSC Visitor's Center which includes numerous exciting space related exhibits including the Lunar Lander and a satellite-capable Amateur station. Regularly scheduled tours of the Center's facilities, frequently including the Shuttle mock-up and Mission Control are available Monday through Friday. Self-guided walking tours will be available Saturday and Sunday.

Registration, several operations related papers and informal get-togethers will begin Friday afternoon October 19th at the Ramada King's Inn adjacent to JSC. The hotel is offering very attractive rates to attendees of $39 per night for a single room and $42 per night for a double. There is a restaurant and lounge on the premises and free limousine service to and from Houston's Hobby Airport is available. For room reservations, call 1-800-255-7345 or 713-488-0220, and state that you are attending the AMSAT Annual Meeting.

This year's Space Symposium will take place in the JSC Visitor's Center auditorium beginning at 8:00 AM Saturday October 20th. It will feature talks on many aspects of Amateur space communication and related subjects. See the accompanying list of papers and events.

Saturday evening's activities include a very reasonably priced Texas barbecue and the AMSAT-NA Annual Meeting; featuring reports on the status of AMSAT-NA and its future plans for furthering the Amateur Space Program, as well as the presentation of awards of appreciation to many who ...made important contributions to ...T and its related activities. These affairs will be held at the JSC Employee Recreation Center.

Sunday's program consists of a series of talks at the King's Inn, emphasizing fundamentals of Amateur Satellite Operation.

Registrations received at the AMSAT office by October 10 are $15.00 for AMSAT members and $20.00 for non-members. Registrations received after October 10, and at the symposium will be $20 for members and $25 for non-members. Registration will also take place at the King's Inn Friday afternoon and evening as well as at the JSC Visitor's Center Saturday morning. The registration fee includes the Symposium Proceedings and shuttle bus transportation between the King's Inn and the two JSC meeting sites.

Please use the accompanying form for reservations. Make your plans NOW to attend this exciting and informative gathering.

As if the AMSAT-NA Annual Meeting and Space Symposium were not reason enough to visit the Houston area during the

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Shown here is Jose Macho of AMSAT-LU with the LU TM Module (W4PUJ photo)

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The AMSAT Journal staff is always interested in editorial contributions from AMSAT members. Text, when possible, should be on diskette (IBM compatible) with hard copy included. AMSAT-NA reserves the right to select material for *The AMSAT Journal* based on suitability of content and space considerations. The editor of this publication as well as editorial contributors are volunteers giving freely of their talents, time and efforts to produce *The AMSAT Journal*. Editor Joe Kasser, G3ZCZ, may be contacted at the Editorial Office listed above.

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Dear Joe ... *This space is reserved for reader's comments.*

SAREX - The Saga Continues

A Letter from W6GO:

The July 1990 article on the subject contained a quotation of a packet message by this writer and comments on it by W3IWI and W2RS. Allow me to make some comments of my own, as listed below.

1. The article says "Apparently Coordination in the Northern California area has not been done". Our use of the frequency 144.95 MHz for DX spotting predates the manned space flights by several years, beginning in 1981. The frequency was used as a two-way simplex interconnect to the Bay Area's voice DX club repeater, and when the Northern Amateur Relay Council of California began sanctioning such simplex operations (including a new mode called packet) in 1985, Sanction 2028 was issued for the simplex use of 144.95 MHz.

The same DX spotting purpose is now satisfied by the PacketCluster network. Now, however, there are full-time nodes on 144.95 in Mountain View, Santa Rosa, Clovis, Santa Maria, Rio Linda and Reno. A backup node is in Stockton. Net-Rom type mountain top nodes (sometimes called digipeaters) are on Ophir peak, Mt. Zion, Bear Mt., and Templeton, serving these nodes. These nodes are linked together via a backbone on 221 and 433 MHz.

Coordination HAS been done. By us, not by AMSAT. We have coordinated with other users and groups and participated as part of Coordination Councils which transcend the individual disciplines of Amateur Radio. AMSAT, where is YOUR coordination document? What have YOU done

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Telemetry Reception with the PK-232

By Howard Sodja, W6SHP @ WD6CMU
4317 Santa Rita Road
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The PK-232 can be used to copy digital signals from all the OSCAR spacecraft now in orbit (except the 400 baud signals from AMSAT-OSCAR 13). This article is a brief summary of how to set up the PK-232 to copy the telemetry from each of them, as well as copying the bulletins and status reports which are sent in plain text for part of each telemetry frame daily on AMSAT-OSCAR 13 and most days on UoSAT-OSCAR 11.

AMSAT-OSCAR 13

The following PK-232 settings will copy AMSAT-OSCAR 13 Baudot RTTY telemetry which is sent on 145.812 MHz on the hour +15 and +45 minutes when operating mode B:-

BAUDOT
RXR OFF
WI OFF
RB 50

The following PK-232 settings will copy AMSAT-OSCAR 13 Baudot RTTY telemetry which is sent on 435.651 MHz on the hour +00, +15, +30 and +45 minutes when in mode JL:-

BAUDOT
RXR ON
WI OFF
RB 50

An oscilloscope connected to the PK-232's monitor jack will simplify keeping up with the Doppler shifted tones as AMSAT-OSCAR 13 passes by, because it is easier to see shift in the cross pattern than a change in the PK-232's tuning LEDS.

If you have an HF RTTY modem you can use this with the PK-232 to improve copy of AMSAT-OSCAR 13, (as well as greatly improve terrestrial HF operation of the PK-232) because the lack of individual tone filters and the use of the 200 Hz shift results in the PK-232 mark/space decoding being less than optimum. I found that with my HF modem's 170 Hz shift (which is AMSAT-OSCAR 13's RTTY tone shift) and separate tone filters I can copy AMSAT-OSCAR 13 RTTY telemetry from horizon to horizon error free, while the PK-232's internal modem will return occasional errors until the signal reaches a high enough strength to overcome the PK-232's modem's band pass (not separate tone) filtering and 200 Hz shift limitations. Also on HF RTTY using the external modem, I can copy weak signals with a greatly reduced error rate.

All you need do to use the external modem is to wire a three pole double throw switch so that the center pins of JP4, JP5 and JP6 are connected to the center lugs of your switch. Then wire the inside and outside pins of JP4, JP5 and JP6 so that the JP center pins are switched to the inside pins for the internal PK-232 modem or to the outside pins for your external modem. The switch can be mounted on the front panel where space permits (like the upper right corner under "model PK-232"). To ease future servicing I recommend that you don't solder directly to the pins on JP4, JP5 and JP6. Check your catalogs (or local electronic supply store) for DIP connectors that are .100 center/.040 square hole size and wire your switch to them. Be sure to mark each connector so you'll always reconnect them to the correct pins in the future. A look at the PK-232 schematic will clearly show you what you are doing. If you can't find a triple pole double throw switch, you can use three DPDT switches. I made do by ganging a SPDT and DPDT together.

Earlier model PK-232's had the middle pins of JP4, 5, 6 connected to the inner pins by means of a circuit trace on the bottom of the PC board. These three traces must be cut. Check beneath the JP pins to see if your model has these traces. Current models use three removable jumpers that will not be needed with the switches.

UoSAT-OSCAR 11

A minor hardware modification is needed in the PK-232 before it will copy signals from UoSAT-OSCAR 11. This is because the PK-232 RXR parameter does not work above 300 baud because of a hardware limitation. The modification to be described performs the equivalent of the RXR operation in hardware, and does it by taking advantage of an unused inverter.

This is what has to be done[1]. U15 pins 1 and 2 must be wired to a switch in series with the output to JP4 as follows:

1. Solder a jumper wire between U15's pins 1 and 6.
2. Cut through the circuit board trace connecting U15's pin 6 to the inside pin of JP4. This trace is easiest to cut where it comes out from under R20 on the top (component side) of the PC board. Be sure to double check that this is the correct trace with an Ohm meter. Cut with care (with a sharp X-ACTO knife) so adjacent traces are not touched.
3. Mount a Single Pole Double Throw (SPDT) switch on the front panel of the PK-232 where it will not interfere with other components (like near the upper left corner by the AEA logo).
4. Connect the center of this switch to the inner pin of JP4 or the trace that goes to it (which was cut to disconnect it from U15 pin 6).
5. Connect the switch contact which will be hardware "RXR OFF" to U15 pin 6.
6. Connect the switch contact which will be hardware "RXR ON" to U15 pin 2.

With your RXR switch in the "reverse" position, the following software settings will now copy UoSAT-OSCAR 11 FM AFSK ASCII Telemetry on 145.825 MHz or on 435.025 MHz:-

ASCII
WI ON
AB 1200

Be sure to return your RXR switch to "normal" when you want to return to regular operation, as this switch is in the signal path in all modes when the PK-232's internal modem is used.

The ASCII downlink tones from UoSAT-OSCAR 11 do not change in frequency with Doppler on the UoSAT-OSCAR 11 because it transmits FM. To the receiver on the ground, it appears that the carrier frequency is changing not the modulation. As a result, you may not get any copy at AOS and LOS if the passband of your radio is narrow. (*Editor's note: I see this effect on my Kenwood TM-2550A*).

Fuji-OSCAR 20 and the Microsats

Reception of the PSK telemetry sent by Fuji-OSCAR 20 and the Microsats requires the use of an external PSK modem. Reasonably priced ones are available as kits from AMSAT-UK and TAPR. TAPR also sells a modem disconnect board kit[2] that plugs into a 40 pin IC socket inside the PK-232 and offers an easy way to interface any PSK modem to the PK-232. The two external modem connectors on the PK-232 do not have the clock signals so using those connectors requires making modifications to the PK-232 circuit board. Installing the modem disconnect board is easier and leaves you with TAPR's two external

modem disconnect ports free so you can now have three external modems. All three of mine are used so I now need four!

Reducing PK-232 RFI

While you have the PK-232 apart, take the opportunity to reduce the RFI it tends to generate. Begin by sanding off all the paint where the two cabinet shells mate and the screws fasten to improve RFI shielding. Star washers under the cabinet screws will also improve grounding. This reduced PK-232 RFI into my receiver. Toroids on all cables connected to your receiver may also help reduce RFI. Those square "snap-together" ones are easy to use. One on my 12 volt line also helped to reduce RFI.

Acknowledgments

Let me take this opportunity to acknowledge the helpful technical staff at Advanced Electronics Applications (AEA) who provided invaluable information.

Notes

1. The UoSAT-OSCAR 11 hardware modification was published by AMSAT-UK in *OSCAR NEWS* (#73), October 1988. For further information, write to AMSAT-UK, 94 Herongate Road, Wanstead Park, London E12 5EQ, England.
2. $17.50. TAPR's phone is (602)-323-1710 and it is manned during the daytime on Tuesday thru Friday. Or write to TAPR, PO Box 12925, Tucson, Az, 85732.

A list of programs for determining satellite passes can be obtained from PROJECT OSCAR, P.O. Box 1136, Los Altos, CA 94023-1136 and from AMSAT, P. O. Box 27, Washington, DC 20044. Everyone interested in satellite activities is invited to check into the Tuesday night East Coast, Central, and Pacific Coast AMSAT Nets on 3840 kHz (+/- QRM) at 8 P.M. local time. Two meter AMSAT nets are also active in some areas. Contact AMSAT Headquarters or PROJECT OSCAR for more information on these nets and for other satellite related information. Join the Space Age today.

Orbital Estimation for Low Earth Orbit Satellites

By Ray Soifer, W2RS
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These days, most of us take orbital elements pretty much for granted. We download them from packet bulletin boards, or find them in *OSCAR News* or in the *AMSAT Journal*, load them into our tracking software, and that's that. These element sets are derived from NASA sources which, in turn, generally rely upon NORAD tracking data. High-powered space-tracking radars scan the skies, looking for all manner of spacecraft. Those so located are compared with an ongoing data base of previously-identified objects to produce the Keplerian element sets to which many have become so addicted.

The Need for Estimation

But what if those element sets turn out to be wrong? Particularly in the early days and weeks of a satellite's life, elements from official sources are often found to be incorrect. The most common source of error is the simple confusion of one object for another. We Radio Amateurs, who detect satellites by listening to their downlink signals and by two-way communication, are almost always able to make positive identification of which birds we are using or listening to; not so with radar since the cross-sections of many satellites frequently turn out to be quite similar. Thus, earlier this year, official satellite trackers had to depend upon AMSAT to help them distinguish the four Microsats and two UoSATs from one another. In addition, official sources mistook both Fuji-OSCAR 12 and Fuji-OSCAR 20 for other satellites with which they were launched: AJISAI and DEBUT, respectively. In fact, throughout the history of the AMSAT program, official object identifications have been wrong more often than they have been right, during the first few weeks after launch.

Accurate official element sets can also turn out to be non-existent. Particularly in the case of manned spacecraft, Amateurs often find themselves in need of accurate tracking data more quickly than the official sources can produce and distribute it. This was certainly the case with the SAREX flight of STS-51F, which carried Tony England, WØORE, in 1985; a partial failure of the ill-fated Challenger's engines left it in an orbit considerably lower than planned.

These and other examples illustrate the need for Amateurs to know how to track satellites on their own and to create or modify element sets to reflect their observations. In this discussion, we shall be focusing particularly on Keplerian elements, since that is the form in most common use today. However, everything we do can be adapted to circular element sets as well. For simplicity, we shall concentrate on satellites in low Earth orbits (LEO) which are approximately cir-

cular, i.e., those having small values of eccentricity. All Amateur satellites launched to date except AMSAT-OSCAR 10 and AMSAT-OSCAR 13, and all manned spacecraft carrying Amateur Radio, fall within this category.

With the aid of some educated guesswork, it is possible to use our own radio observations to develop orbital elements from scratch. After all, that is what a number of us had to do in the early days of Sputnik I and II when officially-derived element sets were not yet available. However, in most cases today, modification of an existing element set, or of pre-launch elements, will be all that is required. In any iterative process, the farther up the learning curve one starts, the better!

Radio Satellite Tracking

Orbital estimation is an iterative process. Accurate tracking observations beget accurate estimated elements, which beget still more accurate tracking. All that we are doing, in essence, is comparing the times at which we observe the satellite with those predicted, keeping track of the discrepancies over time, and modifying or comparing the element sets which gave rise to the predictions in order to improve their accuracy or to identify which element set corresponds to which observed object. No mysteries here! Fundamental to the art, however, is the tracking procedure itself. Specialized equipment, such as that used in ranging techniques, would of course be helpful in some cases. However, the methods described here require nothing more than a good receiving system, an accurate clock, and of course a working system for producing orbital predictions from the element sets under evaluation, such as a computer utilizing SATSCAN or InstantTrack, or even circular elements and an OSCARLOCATOR which will do quite nicely. A CW or SSB receiver, utilizing a stable BFO, is very much to be preferred over an FM receiver for this application since we will be depending upon frequency readings.

In most cases, the best source of data will be the exact time of closest approach (TCA) as measured from the satellite's observed Doppler curve. The Doppler effect, familiar to all satellite operators, increases the apparent frequency of signals from sources moving toward us and lowers the apparent frequency of those moving away from us. At the exact time of closest approach, when the satellite's relative velocity is zero with respect to the observer, the observed frequency will be equal to the actual transmitted frequency. In addition, the rate of change of both apparent frequency and relative velocity will be greatest at TCA as well.

In practice, it is generally easier and more precise to work with actual frequencies rather than with their rates of change. Hence, the exact time (minutes and seconds) when the observed frequency coincides with the transmitted frequency will generally serve as the best approximation of TCA. If possible, choose to monitor a pass as close to overhead as you can; that will generally result in a more accurate reading owing to the shape of the Doppler curve.

Particularly with a new satellite, however, the exact transmitted frequency may not yet have been measured in a space environment with its large temperature changes. There may also be uncertainty as to the calibration of your receiving equipment. One way of resolving both problems for immediate tracking purposes is to note carefully the highest and lowest frequencies which you observe on any particular pass (again, passes close to overhead are to be preferred); the highest frequency will generally occur at AOS and the lowest at LOS. Average the two readings to produce an estimate of the transmitted frequency as received on your equipment; the exact time at which the received signal crossed that average frequency will be your observed TCA.

There will, of course, be situations in which accurate TCA readings will be difficult or impossible to obtain. Manned spacecraft rarely transmit consistently enough to enable a precise TCA to be computed, although with MIR, I have found the 143.625 MHz transmissions to be quite satisfactory for this purpose even though those in the 2-meter band are not. In the absence of TCA readings, accurate determinations of the times of AOS and LOS will have to do. However, these must be interpreted with considerable care owing to the presence of obstacles and over-the-horizon propagation. An experienced operator, knowing the horizon profile and reception characteristics of his station, will be capable of making such interpretations. Wherever possible, however, TCA should be used in preference to AOS/LOS; the results will generally be far more accurate.

Getting Started

Let us assume that we are beginning with a set of pre-launch elements, i.e., one based upon nominal orbital parameters and a nominal launch time. Once we know the actual time of launch, we can update the epoch and right ascension of ascending node (RAAN) to reflect this. Simply adjust the epoch by the number of days and decimal fraction of a day by which the actual launch time differs from nominal, and add to the RAAN an amount equal to 0.98561226 degree multiplied by the amount (in days and fractional days) by which you increased the epoch. Since this is an iterative process, if you do not know the exact launch time, use the best estimate you have.

Take the element set as modified and install it in your tracking software, using a distinctive identifier in lieu of the name of the satellite which will enable you to keep track of which element set it was that produced the results. After all, at this point you do not really know to which satellite the elements actually correspond, do you?

Patterns of Discrepancy

Compare the observed TCA (or AOS/LOS times, if that is all you have) to that predicted by the element set, and note the result carefully for future reference. Make another TCA observation on another pass, then another and another. Again, the process is iterative: the more observations, the better.

After a few observations, a pattern will begin to develop. The observed times might be consistently late or early by a constant time interval. The discrepancy between observed and predicted times might grow at a constant rate with elapsed time, or at an exponential rate. Or, some combination of these effects may be present. Plot your observations against the predictions and attempt to fit one or more of these models to the results. Over a short period (several days or less), the pattern is likely to be a constantly growing time discrepancy between predicted and observed TCA of the form $d = at$, where d is the observed time discrepancy (either positive or negative) and a is a constant, or a steadily growing discrepancy plus a constant (of the form $d = k + at$) in which, in our example, t would be the time interval between the initial epoch and the time of the observation. Over a longer period (e.g., several weeks), an exponential component is likely to be present as well, and the time discrepancy is will be of the form $d = k + at + bt^2$, where b is another constant.

Modifying Element Sets

Now that we have observed a pattern of discrepancies, how do we go about modifying the initial element set to fit? Of the standard Keplerian elements, the ones most likely to be in need of modification based upon our observations are (1) the epoch together with the RAAN, (2) the mean motion, and (3) the decay rate. Remember, RAAN changes by 0.98561226 degrees for each day the epoch is changed. That portion of the observed discrepancy found to be accounted for by a constant — k in our example above — should be dealt with by adjusting the epoch and the RAAN accord-

ingly. A constant delay k of two minutes, for example, would result in adding 0.001389 to the epoch (since two minutes is that fraction of one day) and 0.001369 to the RAAN. Actually, for amounts of less than a degree or so, for all practical purposes the RAAN might as well be left unchanged. Such a constant discrepancy usually is found to result from a delay in launch or orbital separation.

A steadily increasing discrepancy, at, between predicted and observed TCA, after the constant k has been taken into account, means that the mean motion needs to be adjusted. If the satellite is getting progressively later, the mean motion should be decreased proportionally, and conversely, increased if the satellite is getting progressively earlier with respect to the predicted times. Let us say that after 25 hours, 17 minutes, 3 seconds have passed since the epoch time (as adjusted by the constant k, if any), the satellite is getting progressively later relative to the predicted times by a steadily increasing amount, and the latest observation had it 1 minute 35 seconds late with respect to the predicted TCA. The delay of 95 seconds turns out to be 1.04369% of the elapsed time of 91,023 seconds (i.e., a = 0.0104369); we would reduce the mean motion in the element set by 1.04369% of its original value.

For those using circular elements rather than Keplerian, the period and the longitude increment should obviously be adjusted rather than the mean motion. In our example, we would increase the period and increment by 1.04369% of their original values since the longer the period, the fewer orbits in a day and hence, the lower the mean motion.

The newly-revised element set should be stored separately from the original and used to predict future TCAs. Subsequent observations would then be compared with both the original and modified sets, with iterative changes made to the modified set as necessary. If, after several weeks, an exponential component, bt^2, is noted in the time discrepancy, the decay rate should be modified until it predicts the TCAs correctly.

Object Identification

After some time has passed, a few days to a few weeks, revised element sets will begin appearing from official sources. At this point, do not discard your own modified sets, but store the official ones alongside them with their own distinctive identifiers to enable you to identify predictions according to which set produced them (and certainly not which object the author of the official set thought he was tracking). Continue to make TCA observations and compare them against all available element sets, maintaining the accuracy of your modified element set until you are sure that the official sets are correct.

Virtually all satellite launches place more than one object into orbit; remember that the most common source of official error is confusion of one object for another from the same launch. For such launches, there will be multiple element sets, one per object. You will need to determine which official set correlates best with your observations over time; that will be the set corresponding to the object you are observing. As applied to eight objects, this is essentially the technique we used to identify the Microsat and UoSAT payloads from the launch of Ariane V-35.

The techniques I have described can be extremely effective if applied carefully. A set of orbital elements for the Microsats which Bob McGwier, N4HY, and I published 24 hours after launch were still producing results more accurate than the official elements a week later, enabling software uploading to proceed more quickly than if we had to rely upon official tracking data. Using these techniques as the objects separated from one another, the team of AMSAT observers coordinated by KA9Q were able to correctly identify the eight objects launched by Ariane V35 within eight days of launch. Getting the authorities to correct their mistaken object identifiers took somewhat longer!

Manned Spacecraft

Manned spacecraft pose an additional challenge because they carry both people and rocket engines, and the former find it impossible to keep their hands off the latter. An element set may be perfectly accurate one minute and off the next, because a rocket engine "burn" may have altered the spacecraft's flight path.

The tracking method for manned spacecraft is not very different from that for unmanned satellites. You should keep closely in touch with the planned time line for the mission, and, insofar as possible, with the space-to-ground communications to discover possible changes. If an element set that was good begins to develop discrepancies with your observations, it is likely that a "burn" or other maneuver has taken place in the interim. Your tracking of constant and steadily-changing discrepancies with each orbital revolution should tell you how much to adjust the orbital elements (in this case, usually the mean motion) to bring the predictions back into accord with reality. For the short time intervals (a week or less) between manned-spacecraft element sets, the decay rate can generally be ignored.

In the case of unmanned spacecraft without on-board motors, the elapsed time t for purposes of computing corrections to the mean motion is usually taken from the epoch associated with the actual time of launch or orbital separation (the original nominal epoch plus your observed constant k). However, for manned spacecraft, it may be preferable to measure the elapsed time from the time of the most recent engine "burn," or, if that information cannot be determined, from the most recent time at which you knew that your prior element set was still accurate.

Conclusion

Orbital estimation is not only necessary, it is an enjoyable part of our activity besides. It is one way in which we are able to remind ourselves that the authorities do not have all the answers and also a way in which we Amateurs are able to make ourselves useful by assisting them. As you develop some facility with the techniques in this paper, an early contact with a space shuttle, or a MIR cosmonaut, may be your reward!

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Low Budget UoSAT-OSCAR 14 9600 Baud Reception

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Introduction

Any Radio Amateur who starts to assemble a ground station for Packet satellite operation soon becomes aware of the complexity of the hardware involved. Figure 1 shows the typical hardware required for the receive side only, here at GM4IHJ. For simplicity this figure omits all transmitter hardware and connections; all the desirable extras such as Antenna Azimuth and Elevation rotators, as well as masts and preamplifiers. Figure 1 also shows what in some cases, are multi-conductor cables carrying 6 different signal lines as one line.

It should be apparent from that figure that packet satellite operation not only requires a lot of expensive hardware, but also uses a lot of complex cable connections. This means that once the packet satellite station is in full working order, there is a great deal of operator reluctance to taking it all apart in order to operate aurora, sporadic E, moon bounce or some other interesting communications mode of Amateur Radio. Indeed packet satellite operating can be said to have two major drawbacks. The hardware is expensive, and, it becomes doubly so when it ties up expensive hardware for months at a time.

This article reviews experiments and construction projects the author carried out with a view towards lowering the cost of packet satellite operations.

Starting out on 9600 bps

Work began at GM4IHJ in 1989, with the construction of the G3RUH 9600 modem from Jim's printed circuit board (PCB) and suitable components. My expectation at that time was that I would concentrate on receiving the packet satellite Bipolar Phase Shift Keyed (BPSK) signals, however I wanted to try 9600 baud FSK because we plan to use it on terrestrial packet nets here in Scotland. So the chance to do prior tests on a satellite was not to be missed. Note that in rural Scotland sheep greatly outnumber the people. Particularly people using terrestrial communications at 9600 baud.

I knew 9600 baud reception required that the signal audio be taken directly from the receiver FM discriminator, so I modified my ICOM 451 and then sat back to await the satellite signal. Table 1 contains details of modifications to various pieces of equipment to enable them to be used at 9600 baud.

In February 1990, ESA launched the fleet of Microsats, and for two months I concentrated, first on downlink, and then on uplink facilities, to and from the BPSK PACSAT-OSCAR 16, LUSAT-OSCAR 19, WEBERSAT-OSCAR 18 and Fuji-OSCAR 20. By April 90 I was happy with 1200 bps satellite BPSK, so I arranged to do terrestrial 1200 bps BPSK tests with GM4JJJ. These tests were a failure, and despite many modifications to my gear to improve the situation I soon realized that simplex terrestrial BPSK was a non-starter, particularly because of the demands of very tight tuning—easy on a full duplex satellite link, almost impossible for an on/off difficult simplex terrestrial link. At that point UoSAT-OSCAR 14 began sending its very strong 9600 bps FSK downlink.

Right from the start I found I got good Bit Error Rate Tests results, and when UoSAT-OSCAR 14 started sending screen copy I had no problems with reception. The signal was strong and steady, producing more than a dozen pages of screen copy (about 14k of data capture) on very low elevation Polar passes, where LUSAT or PACSAT rarely oblige with a complete screen (2k of data capture at most). Tuning in the UoSAT-OSCAR 14 9600 baud signal was easy. Using the ICOM 451 FM centre tuning meter as a guide. I found I could use 3 or 4 kHz steps to track the signal Doppler shift (as opposed to the BPSK requirement for steps of 100 Hz or less), and get good continuous screen copy, even though UoSAT-OSCAR 14 9600 baud is unusual in that, because of its high keying speed it has no discernible tuning note, and sounds just like receiver noise.

Determined to compare BPSK and FSK, I tried the same terrestrial path as that used 2 months previously for the BPSK 1200 baud tests with GM4JJJ. Those tests on an 8 mile path broken by high ground, had been a failure. By contrast the repeat trial using 9600 baud FSK was a complete success. These terrestrial 9600 baud tests used an old FT221R transceiver.

Full of the praises of UoSAT-OSCAR 14 and 9600 baud FSK, I went to our Scottish Packet Society (MACPAC) meeting and told all and sundry to try copying this excellent satellite. I met a less than enthusiastic reception neatly summed up by local packet stalwart Mike Joyner, GM8FYJ, who remarked that "If you have to take a can opener and soldering iron to your shiny expensive multi mode (rig), and, use it nearly exclusively on 9600 (baud) FSK and 1200 (baud) BPSK, the number of Radio Amateurs getting on Packet satellites will be countable on the head of the proverbial Scottish penny piece".

Unfortunately there is a lot of truth in what he said. Even changing from UoSAT-OSCAR 14 9600 baud FSK to PACSAT 1200 baud BPSK requires that:

a. You either use separate Terminal node controllers (TNC) with all that means in terms of still more cables across the operating bench, *or*,

b. you must change over two 6 or 8 way connectors on one TNC, *and*,

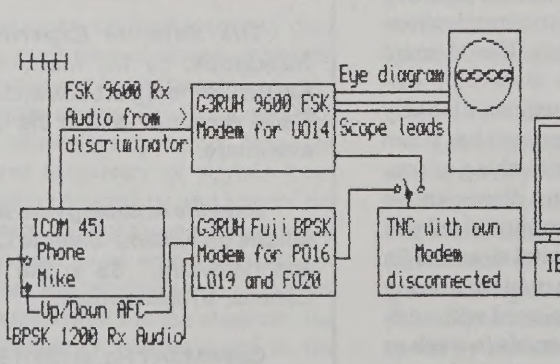

Figure 1 — Typical hardware for packet satellite reception

c. you must reset the Receive baud rate on the TNC, the Terminal baud rate and the computer baud rate if you want to shift from high to low speed copy or vice versa.

d. In addition, you also need to alter the outputs and inputs of both your receiver and transmitter, to change from one modulation mode to the other.

The end result of all the above is that frequent changing soon breaks the plugs and ruins the connectors as well as leaving enormous scope for getting just one parameter slightly wrong and spoiling the whole thing. Building dedicated switch boxes is possible but be warned, very close attention to screening is necessary if you are to avoid "Push to Talk" hang ups and the like.

So determined to prove that there was a simpler and less expensive way to do it I went home from MACPAC and started experimenting, reasoning that UoSAT-OSCAR 14 9600 baud FSK was a much easier first target because of its strong signal and its simple tuning requirements. Figure 2 shows the set up for my first experiment using a Microwave Modules 434/28 MHz converter feeding a Kenwood Trio R2000 receiver in its FM mode tuned to 29.07 MHz. Using a 5 element yagi antenna, I got good UoSAT-OSCAR 14 9600 bps FSK which I removed as received audio data from the output of the receiver FM discriminator. (Modification details are in Table 1).

The R2000 has no centre tuning meter. So I arranged to monitor the received signal "eye diagram" on my oscilloscope, as described in G3RUH's notes which accompany his modem. After a little practice, I found the eye diagram shape to be perfect for tuning. This step is of course essential for 9600 baud reception because the high speed signal has no tuning note, and it comes in so fast most microcomputer screens cannot keep up with it. Hence what you see on your screen may have come in as much as 1 or 2 minutes earlier, and is therefore unsuitable as a real time tuning check.

With this first test I had satisfied myself that any Shortwave listener with an HF receiver fitted with an FM demodulator could copy UoSAT 9600 relatively simply and cheaply. I also tried an R7000 UHF Receiver (needs no converter), and that also gave satisfactory reception of signals from UoSAT-OSCAR 14.

Getting Cheaper

Encouraged by these minor successes, I decided to try something a bit more difficult; tempted by the fact that GM4NUU had an old UK FM 27 MHz Citizens Band[1] transceiver doing nothing. I listened to the

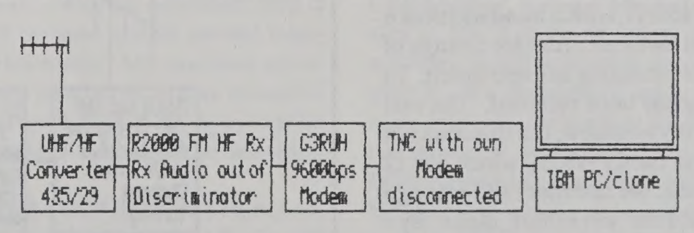

Figure 2 — 9600 FSK reception via a converter and HF receiver

CB for a few days and established that Channels 6 to 8 were quiet at my location, (this test is very necessary - If you have active CBers nearby they may cause breakthrough QRM). So I then sent away an order for a 101.85 MHz crystal to replace the 101.5 MHz Crystal in the high frequency position in an old Microwave Modules 434/28 transverter. The Crystal duly arrived and gave me the UoSAT-OSCAR 14 downlink at approximately 27.67 MHz (435.07 - (4 x 101.85) = 27.67 i.e. near channels 7 and 8).

I didn't expect this first attempt to produce much because the CB could only tune in 10 kHz steps, and to get good copy, the UoSAT-OSCAR 14 9600 baud FSK must be kept in tune by steps of about 3 kHz or less. In the event I got a sequence of :- no tune at Acquisition of Signal (AOS) as the signal was half way between Ch8 and Ch7. Then for 2 minutes or so it Dopplered through Ch7 giving reasonable but not perfect screen copy. Then I had to wait 5 minutes whilst it Dopplered down to Ch6, and there I again got 2 minutes useful copy. This was a good start but clearly in need of inter channel tuning. So I had a go at pulling the CB tuning oscillator but found I could only shift it 500 Hz rather than the 10 kHz I needed. I then tried pulling the transverter local oscillator with serial capacitance and found after some experiment that I could get smooth shift over 11 kHz using a slow motion 5-60 pF variable capacitor in series with the Crystal. A test on the next pass established that I could now tune the beacon signal starting at about the middle of channel 8 switching to Ch 7 and tuning high at first, then through the tuner range, before switching to Ch 6 high at the end of the pass. The only problem remaining was the poor quality of the system bandpass evident on the oscilloscope eye diagrams.

To find out where the bandwidth problem lay I had to follow the UoSAT signal down through the receive signal path starting at the 10.7 MHz first IF of the CB radio and then on into the 455 kHz 2nd IF. Using a probe attached to the antenna input of the R2000 Receiver tuned first to 10.7 MHz then to 455 kHz, I established that the problem was occurring at the 2nd IF Ceramic filter. Checks showed this to be a Murata CFW455HT with a bandwidth of 6 kHz. So I sent away an order for a range of broader filters intending to experiment. To date only one has been received. The rest are not presently available, but this does not matter because the CFW455F which has 12 kHz bandwidth, the one that I did manage to get, produces excellent clean eye diagrams and first class horizon to horizon copy. So I can wait until later to see if I can get the other filters, because even if I do not need them now, I will probably find them essential when I get to try 19.2 kbps.

As Figures 3 and 4 show, I now had my cheap Converter (or transverter)/CB UoSAT-OSCAR 14 UHF 9600 baud receiver, and more recently, I have converted the CB transmit side to varactor

Table 1 — Equipment Modifications for reception of UoSAT 3 9600 baud FSK

Equipment	*Modification Details*
UHF/HF Converter 434/28MHz Use with HF FM Rx unmoded. Or with CB,use+ Crystal+tuner	None if used with HF FM Receiver tuning 29.07MHz For use with UK 27.61 FM CB. Fit replacement L osc 5th overtone 101.85 MHz Crystal. Wire a 5 to 60pF approx variable capacitor in series between Crystal and Earth. If necessary fit the whole in a bigger box.
Kenwood R2000 Rx Use with unmoded converter 434/28	Wire screened lead from FM discriminator at common point between R207, R209, R210, C200, and C202, to an additional jack socket on Receiver (Rx) back plate.
ICOM R7000 UHF Rx No additions necessary	Wire screened lead from FM discriminator on IF unit at common point of R97 and R96, to spare position on rear back plate of Rx.
FRG 9600 UHF Rx No additions necessary	Wire screened lead from pin 9 IC MC 3357 FM discriminator on N.FM UNIT F26821011 (accessory board near middle of Main Board), to Record socket at back of receiver, replacing existing R53 feed.
UK FM CB HF Use with modified UHF/HF transverter or converter	Used with transverter, separate Tx and Rx antennas Used with converter, disable CB transmitter Replace 2nd IF ceramic filter for wider Murata 12kHz CFW455F (usual fit CFW455HT which is only 6kHz wide) Fit an Rx Audio output jack on Rx back panel and wire it via screened cable to pin 9 of FM discriminator chip (usually MC3357).
FT 221R 2m TxRx	Used for 2m reception tests of uplink to UoSAT-OSCAR 14 by taking Rx Audio out from card PB-1463(FM IF) connection 2, via screened lead to one of the relay sockets on the back panel after first disconnecting original output.
ICOM 451 UHF TxRx	For 9600 bps reception wire a screened cable from pin 9 of IC7 MC3357, to one of the spare terminals at the transceiver rear plate.

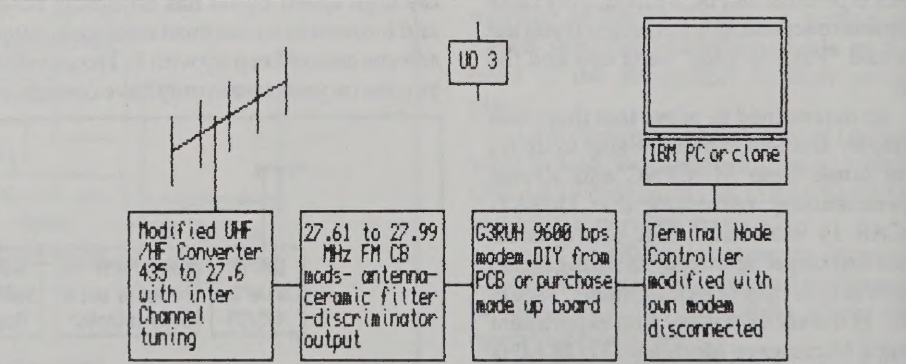

Figure 3 — A simple receiving station for 9600 baud FSK from UoSAT 3

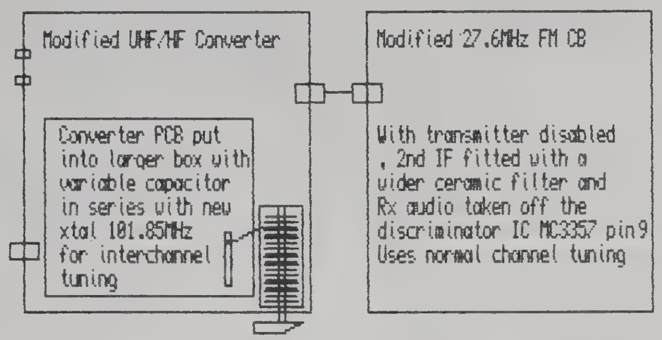

Figure 4 — UHF/HF Converter and CB hardware for low budget UO3 9600 baud FSK reception

input. With this coupled to the transverter with both the high band 101.85 Crystal and a new low band Crystal of 101.25 MHz I can use the transverter/CB for both UoSAT-OSCAR 14 reception and also for two way terrestrial 9600 baud FSK or 1200 baud AFSK UHF packet. Total out of pocket costs were that of the two Crystals and one filter, 12.20 pounds or $19.20.

Other Cheap Solutions

Mike, GØMJW, and several other Gs have succeeded in modifying UHF pocket phones to receive UoSAT-OSCAR 14, in some cases by adding external improvements like discriminator chips and ceramic filters. Suitable chips are the MC3357P and the MC3362, when fed with a 10.7 MHz output from the pocket phone. As another alternative, David Anderson, GM4JJJ, is experimenting with a cheap FM scanner on which he is trying to get automatic frequency control to solve the tuning problem completely. Others, GØMJW for example, have demonstrated that they can copy UoSAT-OSCAR 14 9600 baud FSK on a UHF pocket phone inside a car (safely parked at the time). So further progress can be anticipated.

We also need similar cheap solutions for BPSK reception. I appreciate that this is not likely to be so easy, with AFC being an absolute essential. Microsat BPSK fans should be able to come up with something, perhaps using old American SSB CB outfits.

All of this leads to a final point whereby it is particularly noteworthy, that here in Europe, a great many Radio Amateurs, while not strictly interested in becoming fully fledged two way satellite users, are looking for cheap ways to read satellite packet broadcasts of bulletins and telemetry. Terrestrial packet has shown many non-satellite users that there is a lot of valuable information they could be missing out on, and many of the GMs in this group tell me they are looking forward to receiving UoSAT-OSCAR 14 bulletins. Let's hope they then graduate to full two way satellite usage.

Clearly different people will find different solutions to the problems of cheap 9600 baud FSK, and, 1200 baud BPSK reception, depending on what is in their junk box, or is locally available. Perhaps you can write to the Journal Editor with details of your solutions.[2] Meanwhile, any comments, good, bad, rude or kind, will be gratefully received by GM4IHJ @ GB7MAC.

Notes

1. In the UK, the 27 MHz Citizens Band uses FM not AM as used in the USA.
2. I'll second that, *Editor.*

Off the Pad

Telemetry: Our Greatest Asset

A personal opinion by Joe Kasser, W3/G3ZCZ*

In the past AMSAT's membership has always been thought of as the Amateur Radio communicators. We have given lip service to education and non-communications experimentation, and haven't really treated those aspects seriously. I'd go further than that and say that we have (in practice) actually discouraged them. All our satellites apart from the UoSATs and WEBERSAT-OSCAR 18 were designed as communications satellites, the telemetry aspects are secondary. AMSAT-OSCAR 13 sends back 50 baud RTTY telemetry and 400 baud PSK telemetry which requires a special terminal unit. While UoSAT-OSCAR 9's ASCII telemetry could be copied with a PK-232, UoSAT-OSCAR 11 can't be copied with a PK-232 without hacking it so that most people (at least outside the UK) tend to ignore it. UoSAT-OSCAR 11 and AMSAT-OSCAR 13 send back BAUDOT or ASCII data, and fades cause errors in reception. I have seen very little published about the findings of those scientific satellites. WEBERSAT has been somewhat better, but I have yet to see a definitive article describing the payload experiments and the use that the telemetry can be put to.

The real telemetry spacecraft of the OSCAR series have been the UoSATs yet most Radio Amateurs don't even give the UoSATs the time of day. Why? Is it because schedules are not published with the result that the times the UoSAT-OSCAR 11 digitalker is active are not known? Is it because information on using the downlink data is lacking? Is it because people are not interested in the telemetry? My previous editorial triggered a number of articles related to telemetry, so there does in fact appear to be interest out there amongst the membership.

When Fuji-OSCAR 20 was launched, people equipped for Fuji-OSCAR 12 were able to use it and copy the telemetry. However without the information to decode the data, they soon lost interest and stopped copying the telemetry on a regular basis. When the Microsats went up, people who had 70 cm capability copied the Microsats not the UoSats. Why? They were not set up as digipeaters at that time. Their telemetry was straight forward and could be seen as ASCII characters on any terminal screen. People knew that within a few weeks they would be able to decode the packet data. Is it because the UoSATs data formats were changing - yuch? Once the thrill of receiving satellite telemetry wears off, and it does so very quickly, without any means to know what that raw data means, people lose interest. That's why telemetry decoding information and software was published and posted in the *AMSAT Journal* and on Compuserve. It doesn't matter if the telemetry is ASCII digits or binary bytes; some software is still needed to decode and display it. We are already using software in our computers to interface the TNC, so why not have that little more in it to decode the telemetry and display engineering units. It is easier to manually decode the telemetry if it is in ASCII, but how many people are going to do that for very long?

When the Microsats went up, we told

the world to listen to DOVE on 145.825 MHz. Its telemetry was simple conventional packet. With an HT and a TNC anyone could copy packets from space and see ASCII numbers on the screen. DOVE generated a tremendous interest in the AMSAT-OSCAR program which has since waned. From the educational point of view, DOVE, once fully operational, is an excellent idea. It leads people gently into satellites. It seems like almost every ham in the world has a 2 meter HT. Starting with DOVE, they one day will be able to hear voice messages on it. When receiving those voice messages begins to pall, those who want to receive the telemetry need only get a TNC and a computer or terminal. Once they have packet capability, they can concentrate on data analysis or, can upgrade slowly to full duplex communications via the other Microsats and Fuji-OSCAR 20. The migratory path is there.

DOVE's prime mission is to send various voice synthesized messages. As the weeks went by, there were no voices from DOVE. Telemetry yes, voices no. More and more people became interested, then began to lose it again. They couldn't do anything with the data once they saw it, and, watching temperatures drop as the spacecraft went by each evening became boring after a while. Then DOVE's CPU crashed! Getting DOVE back on the air was not a simple project, two onboard hardware failures made the job very difficult, and the volunteers who performed that task deserve a massive vote of thanks from all of us. When DOVE went silent, AMSAT's most visible aspect to the educational and Radio Amateur community had disappeared. DOVE has the potential capability to generate interest both in space science and Amateur Radio; and also attract membership to AMSAT. A few weeks after that incident, the Microsat telemetry format was changed to binary without prior warnings. How to turn people off in one easy lesson! Yes, we were told that the formats could change, but most of us assumed that meant changes in the channel assignments, not a change in format from ASCII to Binary. Yes, there are times when whole orbit data (WOD) are required, and there are times when command stations have to do certain things. We set up Wednesdays as experimenter's days for some of that. Even so, software developers can do their special thing then put the spacecraft back into a mode so that the general public can use the spacecraft. Don't misunderstand, I'm not against binary format telemetry, in fact I can see many advantages to it, I'm against the way the changes were made. In my opinion, telemetry is our future, we should encourage it not discourage it.

DOVE is back on the air. Interest in the space program is climbing again. As this is being written, SAREX is coming up. The articles in the *Journal*, *QST* and *73 Magazine* have given AMSAT a lot of publicity. Not only is there interest on behalf of the packeteers, but there is interest further afield. Ron Parise, WA4SIR, indicated to me in February 1990 that he had received over 500 requests for scheduled voice contacts as part of the SAREX. He will only have time for about 5 such demonstrations. This year we have STS-35 and STS-37 going for us. Are we going to take advantage of the publicity they'll generate, just like the last three STS missions that featured ham radio and the Skitrek that generated a lot of interest in the educational world or are we, once again, going to do nothing?

Interest could be kindled in terrestrial telemetry by adding sensors and a transmitter to FM repeaters. However any concept has greater appeal if a spacecraft is involved. The big advantage the Microsats have over AMSAT-OSCAR 13 and UoSAT-OSCAR 11 is that the packetized telemetry is received error free. If you copy a valid packet, the data is good. We could start kindling interest with an existing OSCAR spacecraft. We could even utilize more than one spacecraft. There are eight of them up there and operational now, let's make a start with them. Let's begin with what we have and go from there towards a Satellite for the Understanding of Space Instrumentation and Experimentation (SUSIE).

We could even make a start with DOVE. Now before I make any suggestions for the use of DOVE, I must point out that DOVE does not belong to AMSAT, it belongs to BRAMSAT who will decide how it is to be used. Still, here's my recommendation. When we put DOVE on its proposed and publicized voice schedule, let's intersperse those messages with short telemetry packets every few minutes. This schedule would allow the schools to receive the voice messages and yet also allow for automatic unattended data reception for subsequent further analysis. Let's then look to SUSIE as a follow on activity. SUSIE could be a whole spacecraft using Microsat technology. Such a spacecraft would contain sensors that would send back information which could be directly related to propagation conditions, data which would show the spacecraft's orientation with respect to the Earth's magnetic field, as well as the usual temperature and solar panel information.

On the other hand, NASA has a 'Mission to Planet Earth' project to provide an Earth Observation Platform (EOP) in 1997. SUSIE could be an attached secondary payload (ASP) to that platform, transmitting packetized telemetry data in the 2 meter band. In that incarnation, SUSIE could really bring not only the space program, but the educational and scientific use of space, into every educational institution in the country. Nobody ever said that hams had to build whole spacecraft. The Russian Radio Sputniks are ASPs, why can't we build similar packages for true educational usage?

The major difference between SUSIE and the UoSATs is that the concept would be "marketed" ahead of time. The science data formats and preliminary equations would be published months before the launch. A secondary market would arise from the rudimentary beginnings spawned by the weather satellite receiving equipment industry. Software and simulators would be developed before launch. AMSAT would benefit from this nationwide, nay global increase in awareness of outer space. Our membership would increase. We might even benefit from royalties from the sales of ground station equipment and software. Do you realize that AMSAT has received more than $100,000 from sales of satellite tracking software (for all types of computers) over the last two years. Imagine the revenues if we "marketed" the SUSIE concept in the educational and in the amateur astronomy markets; areas that we have long neglected. Think of the potential revenues if only 10% of the schools in the country purchased at least one copy of InstantTrack, how about if 20% bought it, or even more? Think of the use we could make of those revenues on the Microsat, Phase 3 and Phase 4 projects.

Now to make this happen, we first need user friendly software to decode and display the telemetry data. If you are wondering about the lack of telemetry decoding software, well it is currently being written only because the programmer wants to see what kind of information the spacecraft is sending. If each spacecraft uses a different format, the software has to contain a different decoding module for each spacecraft. If the format for a particular spacecraft changes, the software has to be revised. After a number of such changes, the programmer loses interest in following the changes made by the engineering team and goes on to other activities. There is no mass-market for this kind of software at present, so there is no financial incentive to write it.

We need standard formats for telemetry transmission and archiving. With a standard, we will not end up with a plethora of packet types from the same spacecraft. We will be able to identify when

(Continued on page 30)

Microsat Motion and Stabilization
(and why we care about it)

By Jim White, WDØE @ WØLJF
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Littleton, CO 80123

About the Author

Jim White, WDØE, has been licensed for 26 years and currently holds an Extra Class. He played a small role in the construction of the Microsats, assembled the ground stations used in the lab and at the launch, and is a member of the CSDP. He co-authored a telemetry decoding program for the Macintosh and has been concentrating on Microsat telemetry, especially related to motion, since launch. He is also active as the sponsor of an Amateur Radio Explorer Scout Troop, teaches the Extra Class with the Denver Radio Club, and participates in the SKYWARN program. Jim is employed at US West as a computer projects manager.

Introduction

Signals from the Microsats fade seemingly at random during a pass. What more, the fades seem to be different on every pass. One likely reason is polarization changes caused by Faraday rotation of the signal as it passes through the ionosphere. Another is the motion of the spacecraft. A better understanding of the motion and its potential effects on the signals from the spacecraft may be helpful in understanding how to design the most effective ground station antennas. Additionally, since the attitude stabilization method used for the Microsats is nearly unique, and is garnering some interest from the aerospace community, this paper takes the opportunity to document it.

This paper discusses spacecraft construction features that relate to stabilization and motion, the theory of the stabilization method, and telemetry channels and data that can be used to determine spacecraft motion and attitude. It then reviews the initial motion after launch, including the surprise handed to us by PACSAT, and the current situation. It concludes with a summary of the effect of the motion on signals from the spacecraft and some areas that need further study to complete our understanding.

Construction information related to stabilization

In order to understand the stabilization method and the motion of the Microsats, we first have to know a bit about their construction.

The 'top' of the Microsats is the +Z surface (see Figure 1). This is the one with the 2 Meter antenna projecting from the center, and is normally 'up' in photographs. It is also the surface that is up when the spacecraft are mounted on the launcher (Note 1). On the opposite side of the spacecraft is the -Z surface, the one by which the spacecraft were mounted to the launcher. A line drawn vertically through the spacecraft, passing through the center of each Z surface, is called the Z axis. The sides of the spacecraft are named the +X, -X, +Y and -Y surfaces. When looking down on the top surface (+Z), and arbitrarily assuming the +X is at the top of your view, the +Y is on the left side, the -X at the bottom, and the -Y at the right. Lines drawn through the spacecraft and the centers of these surfaces are called the X axis and the Y axis.

There are four magnets mounted parallel to the Z axis, one at each corner of the spacecraft. In PACSAT-OSCAR 16, WEBER-OSCAR 18, and DOVE-OSCAR 17, they are arranged so that their -Z end is attracted to the Earth's north pole, in LUSAT-OSCAR 19 they are mounted with the opposite polarity.

The downlink antenna blades are painted white on one side and black on the other. These are canted turnstile antennas and are mounted around the edges of the -Z surface, centered on each side. On PACSAT, DOVE and WEBER if you are looking at the -X side, you see the white side of the blade on the left (below the +Y side) and the black side of the blade on the right (below the -Y side). The blades below the X surfaces are oriented similarly. When looking down on the +Z surface, this means that the white sides all point in the 'counter clockwise' direction. On LUSAT, the blade sides are oriented in the opposite direction.[2]

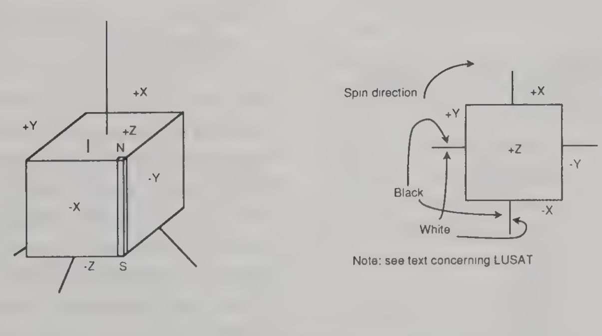


Figure 1 — Microsat surfaces and solar propeller blades

There are seven lossy iron rods (hysteresis rods) mounted in the bottom of the battery module in the XY plane and aligned with the X axis.

Expected in-orbit stabilization mode

The stabilization method used with the Microsats is quite simple compared to many sophisticated (and expensive) satellites. It has been used with previous AMSAT spacecraft, yet continues to be refined. A scientifically complete description is beyond the scope of this paper, however, this section provides an overview that should help in understanding the motion of the spacecraft. It will be related to expected signals in a later section.

The Earth's magnetic poles are not located at the geographic north and south poles. The north magnetic pole is actually located near the northwest coast of Greenland at about 78.8 degrees north and 70.9 degrees west. The south magnetic pole is near the coast of Antarctica at about 150 degrees east.

The lines of force of the Earth's magnetic field are nearly perpendicular to the surface of the Earth, except between about plus and minus 30 degrees of the magnetic equator (see Figure 2). The equation for determining the slant of the field lines to a line perpendicular to the Earth's surface is:

$$b = 90 - \operatorname{atan}(2 \cdot \tan(g)) \qquad \text{(Equation 1)}$$

where

b = the angle of the magnetic force line to a line drawn from the center of the Earth through the surface at latitude g.

Note that g is the geomagnetic latitude, not (necessarily) the geographic latitude.

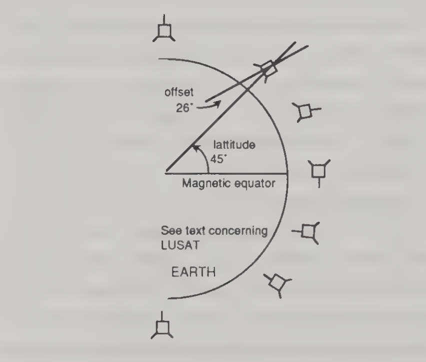


Figure 2 — Nominal tilt within orbit plane

This is an important angle because it indicates the Z axis tilt from the perpendicular. This means, for example, that at 60 degrees geomagnetic latitude, the downlink antennas will be off pointed from the local vertical by about 16 degrees. Since the magnetic poles are offset from the poles of rotation, the magnetic equator is also offset from the geographic equator. At the longitude of the Americas, about 100 degrees west, the magnetic equator is about 15 degrees below the geographic equator. Hence it does not cross South America in Colombia, but about 15 degrees further south, in Brazil. Thus, the offset from perpendicular at the latitude of the northern border of the US (about 70 degrees geomagnetic latitude) is about 7 degrees, and at Florida (about 60 degrees geomagnetic latitude) it is about 16 degrees. Directly over the magnetic equator, the lines are parallel to the Earth's surface. Table 1 lists these angles for several latitudes.

The Microsats are in a polar orbit that is sun synchronous. To each spacecraft it is always 10:30 A.M., as it stays in the same place relative to the direction of the sun, and the Earth rotates under it. To achieve this effect, the orbit is tilted slightly, so it doesn't pass directly over the geographic poles, but misses them by about 10 degrees or 500 miles. This means that the ground track will cross directly over the magnetic poles on some orbits and miss them by a considerable distance on others (see Figure. 3).

The magnets along the Z axis of the spacecraft line themselves up with the lines of the Earth's magnetic field in a mode generally called "passive magnetic attitude stabilization". This holds the spacecraft

Table 1 — Offset from the perpendicular at different geomagnetic latitudes

Geomagnetic latitude (g)	Offset (b)
90 (pole)	0
75	7.6
60	16.1
45	26.6
20	53.9
0 (equator)	90

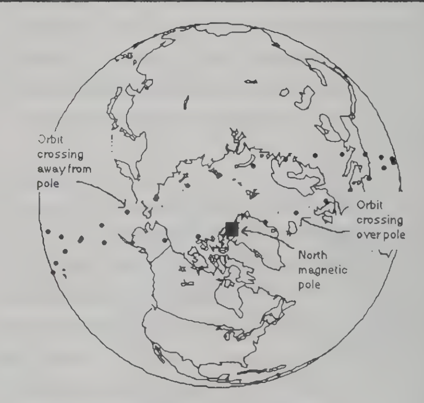


Figure 3 — Relation of orbits to magnetic pole

with the Z axis nearly perpendicular to the Earth's surface, except when it is near the magnetic equator. Either the +Z surface or the -Z surface will be 'up' or away from the Earth, and the tilt of the Z axis to the north or south will match the angle of the Earth's magnetic field lines at that latitude. During an orbit as the spacecraft nears the magnetic equator, the top surface will be pulled toward the direction of motion until the spacecraft is flying with the Z axis parallel

to the Earth's surface. After passing over the equator the leading surface will be pulled down until it is pointed at the Earth, and the spacecraft has completed a 180 degree roll. The opposite Z surface is now down and the Z axis is again about perpendicular to the surface, varying by the tilt of the force lines as described in Equation 1 and Table 1.

While the Z axis stays locked into the Earth's field lines, the spacecraft spins about the Z axis because of the pressure from solar radiation on the downlink antenna blades. Solar pressure is greater on the white sides of the blades than the black, so the spacecraft spins in a counter clockwise direction when viewed from the +Z side (except for LUSAT, which is opposite). This spin mode is officially known as "photon assisted spin" but is commonly called the "solar propeller".[3] The spin rate was expected to be about 3 minutes per revolution for PACSAT and LUSAT, about 3 times that for DOVE, and slightly slower than that for WEBER. DOVE should be faster because its painted antennas are for 2 meters and are about 3 times the length of the 70 cm antennas on the others. WEBER should be slower because of its larger moment of inertia. The hysteresis rods damp forces acting on the spacecraft and prevent excessive motion. It was expected that the speed of the spin would increase until a stable rate was achieved; that rate being a balance between the torque generated by the solar propeller and other forces acting on the spacecraft. The increase in rate would at first be quite fast and would decrease exponentially until that stable state was reached.

During sunlit parts of the orbit it was expected that the spin rate would increase slightly, then would decrease when the spacecraft is in eclipse. Some seasonal variation in spin rate should also occur as the percentage of the orbit that is in sunlight changes. This rotation provides thermal control of the spacecraft by ensuring that the sun heats each surface in turn.

All of these factors must be carefully balanced. Too much spin can introduce enough gyroscopic effect to prevent the spacecraft from rolling over at the equator. Not enough spin and the spacecraft may tumble. If there is not enough strength in the magnets the spacecraft will not lock on the field lines and will also tumble. Many factors can upset this balance and cause very complex motions, which are undesirable. This stabilization method is strictly passive, no adjustments can be made once in orbit.

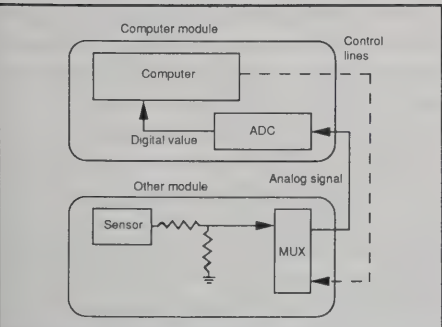


Figure 4 — Telemetry diagram

The intent of keeping the 70 cm (2 meters for DOVE) antennas down when over favored areas is to maximize efficiency on the downlink, which is expected to be the weaker link.

Telemetry measurements in the Microsats

The telemetry capabilities of the Microsats provide excellent means to study their motion. Samples can be taken as often as every 5 seconds and the 1200 baud downlink speed (higher speeds are possible) provides adequate bandwidth to send extensive telemetry data. Additionally, the whole orbit data (WOD) facility allows the collection of several telemetry points for up to about 5 orbits (limited by available memory). This is an invaluable tool for studying all aspects of the operation of the spacecraft. Several of the telemetry channels useful in studying motion are described in the following section.

In a Microsat, each module except for the computer, has one or more sensors (voltage, current, temperature, etc.) that is part of the telemetry system (see Figure 4). Many of the signals from these sensors are wired through a resistor voltage divider in the module before being connected to the input pin of an analog multiplexor (MUX) chip located in each module. The on-board computer (OBC) selects the module and the sensor to be switched through the MUX to the single analog sampling lead that is part of the spacecraft wiring bus. That lead is connected to the analog to digital converter (ADC) chip in the computer module. The digital output of the ADC is made available to the OBC and can be sent in real time as a telemetry (TLM) channel, stored for later download, etc., all under on-board software control.

The voltage dividers in each module are necessary because the input range of the ADC is 0 to 2.5 volts, so all signals must be scaled down to that range. The published TLM decoding equations[4] compensate for the scaling of the voltage divider and convert the directly measured voltage to its appropriate engineering value (Amps, degrees centigrade, etc.). Some channels have no units, so we refer to their values in 'counts'. The infrared (IR) sensors are a good example.

For some TLM channels a single bit change results in a larger change in the calculated (or engineering) value than you might expect. This is because the ADC is an 8 bit device and can only separate input voltages into 255 parts, and because of constraints in the voltage and current capabilities of the sensors. For example, a one bit change in raw value of temperature TLM channels from DOVE results in a 0.6 degree change in the calculated temperature.

The TLM decoding equations were derived from calibration measurements made both in the AMSAT Boulder Laboratory and at the launch site in Kourou. Those results were plotted and then software was used to fit a curve to the results and derive the TLM equations. In some cases few data points were available to derive the equations. In other cases a quadratic equation will not fit the calibration data. Therefore there are some built in errors in the equations. Adjustments may be made for those errors at some time in the future by either updating the equations or using completely new decoding methods such as look up tables. In the meantime, what we have is reasonably accurate and quite useful.

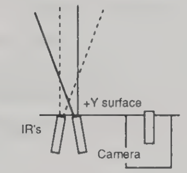


Figure 5 — WEBER IR sensors

Telemetry useful in motion studies

The primary source of motion study data to date has been the solar array currents. An additional valuable input on DOVE, PACSAT, and LUSAT is the IR sensor which looks out the +Z surface. On WEBER, there are two IR sensors mounted on the +Y surface, the same surface the camera looks out of. There are also two magnetometers in WEBER, measuring magnetic forces in the XY and YZ planes.[5]

The +Z IR sensors are designed to show when the +Z surface is pointing at the Earth. Their scale is in units and is logarithmic: The larger the count, the more light is striking the sensor. This data is somewhat noisy. It sometimes varies from the actual value by a count or two due to slight bus voltage variations, AC on the source voltage, RFI, or other reasons yet to be determined.

WEBER has no +Z surface IR sensor (see Figure 5). It's +Y IRs looks slightly to the left and right of the direction the camera points (perpendicular to the +Y surface). They form an angle between them of 22 degrees and their conical field of view is 10 degrees. They are positioned so that the only time they are illuminated simulta-

neously is when the +Y is facing the Earth. The intent of this design was to allow their use to assure pictures were taken only when the camera was pointed at the Earth. Their readout is opposite the other spacecraft's IRs: Illumination decreases their count. This data is also somewhat noisy.

A temperature sensor was mounted on the inside of the +Y solar array on each spacecraft. One of the reasons for this location was to provide an additional point that could be used for attitude and motion determination. However, it has turned out that the solar panel is a good enough insulator that the temperatures as measured by these sensors only reflect the general warming and cooling of the spacecraft during the sunlit and shadowed portions of the orbit, and do not change noticeably as the spacecraft rotates.

The temperature sensor mounted on the top module cover (+Z side) can be used to roughly determine when the +Z is in the sun. Temperatures here will lag sun illumination by a few minutes because it takes a while for heat to be transmitted through this surface when the spacecraft comes out of eclipse.

The WEBER magnetometers were designed to allow measurements of the Earth's magnetic field. Magnetometer 1 is oriented to sense flux lines in the YZ plane of the spacecraft, and magnetometer 2 measures flux lines in the XY plane. Each of these sensors was biased with a small permanent magnet mounted near it to cancel the effect of the stronger spacecraft attitude control magnets. Proper operation of these sensors has not yet been verified. If working as designed they may be useful in motion studies.

By far the most useful telemetry channels have been the solar array currents. Since the current from the solar arrays changes essentially instantaneously as a function of the angle of sunlight on the panel, that angle can be calculated with reasonable accuracy for every surface that is in the sun every time a TLM sample is taken. This allows us to determine the angle of the sun on either two or three surfaces every x seconds, where x is the TLM sample interval. Since we know the angle of the sun to the plane of the orbit is 22.5 degrees all the time, that amount can be factored out and the angles of the surfaces to the orbit plane can be determined. The equation for calculating the sun angle from the array current is:

a = acos(Inow/Imax) (Equation 2)

where a is the angle
Inow is the current measured
Imax is the maximum current the panel is capable of producing.

Imax will be 351 mA plus or minus 2 mA for every panel on each of the Microsats except the -Z panels, since they contain half the number of cells. The result of this calculation using many computer spread sheets will be in radians and must be converted to degrees by multiplying the result by 180/Pi. Using Equation 2, when there is no sun on the panel the calculated angle will be 90 degrees, and when the sun is directly on the panel (perpendicular to the panel surface) the angle will be 0 degrees. Since that is not the way we usually think of angles to surfaces, we can take the complement of the angle (subtract it from 90) and the result will be the angle between the direction of the sun and the panel surface. Thus the more complete equation is:

a = 90-(acos(Inow/Imax)*Pi/180) (Equation 3)

See Figure 6 for a chart of this relationship.

This formula is not accurate at shallow

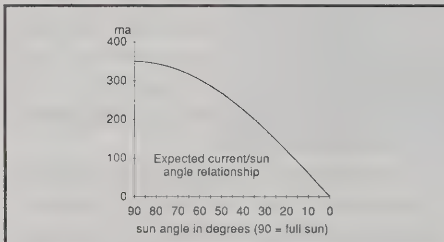


Figure 6 — Expected Microsat current/sun angle relationship

sun angles because of scattering from the solar cell cover slides and array shadowing as explained below. That is why the telemetry decoding equations give negative results when there is no sun on the panel. Work needs to be done to further refine this equation, but it appears to be quite accurate above about 15 degrees of sun angle.

The effect of the shadow of the antennas falling on the solar panels is noticeable. The antennas are made of 3/8" Stanley tape measure material, therefore they will cast a 'thin' shadow and a 'thick' shadow depending on their orientation to the sun. Their long side is parallel to the X axis. The uplink antennas will shadow the +Z array all the time the +Z surface is in sun, since they project upward perpendicular to the +Z surface from the center of it. The downlink turnstile antennas will cast a shadow on the -Z surface at times, and on the side they are mounted below at other times. The effect on array current outputs when shadows are cast on the various panels, both for a nominal attitude and for situations when the spacecraft is nutating (wobbling), remains to be studied.

The spacecraft spin rate can be easily determined by examining array currents. The best way to do this is to plot them with a computer. See Figure 7 for an example of an ideal case. Note that the vertical (Y) axis of the graph is current and the horizontal (X) is time. Points on the X axis are 10 seconds apart. With nominal conditions we expect each of the side panels to rotate into the sun and out again as the spacecraft spins around the Z axis. A plot of the X and Y surface array currents will show the current from one surface start out at zero, slowly climb to a maximum, then drop to zero again, as it rotates into then out of the sun. As an example, let's assume the +X panel is fully in the sun. Its array current will be about 340 mA. This is the expected current with a sun angle of 22.5 degrees, the nominal angle of the sun to the orbit plane. No current will be generated by the other X panel because it is in full shadow on the 'back' side of the spacecraft. The Y panels also will not be generating current because they are parallel to the suns rays. As the spacecraft rotates (counter clockwise as viewed from the +Z), the current from the +X panel will slowly drop and the +Y panel will start to generate current as it comes into the sun. When the spacecraft has rotated 45 degrees the +X and +Y panels will be receiving equal sun and be generating equal current. 45 degrees later only the +Y panel will be in sun and the +X current will drop to zero because it has passed into shadow. This pattern continues as the spacecraft rotates. To calculate the spin rate, count the number of seconds between the peaks of two successive panels and multiply by four.

If there is nutation about the Z axis, and the period of the nutation is short compared to the rotation rate, the current plots from each array will be a wave superimposed over the nominal rise and fall described above. They can be pictured as a higher frequency cosine wave imposed on top of the positive half of a lower frequency cosine wave.

Initial motion and current situation

The spacecraft were mounted on the launcher with a single explosive bolt ex-

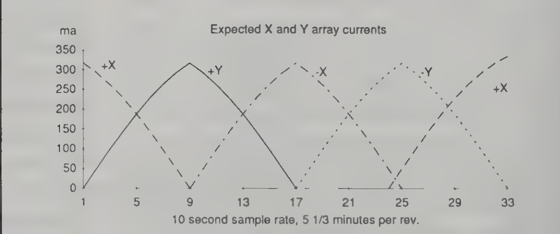


Figure 7 — Microsat ideal case X and Y array currents

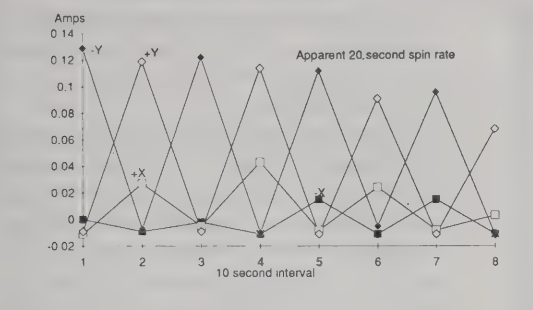


Figure 8 — DOVE array currents on 2-17-90

tending from the center of the -Z surface through a spring to a ring (the Auxiliary Secondary Payload Adaptor (ASAP)) around the bottom of the payload section of the Ariane IV launcher.[1] The +Z surface was pointed straight up as the vehicle sat on the pad. Each spring was a slightly different strength. After SPOT 2 and the UoSATs were deployed, the Ariane third stage and payload section was pointed backward (top opposite the direction of flight) and the explosive bolts were fired, allowing the springs to pop the Microsats off the ASAP. Over time the spacecraft became separated because of the different spring strengths. The torque generated by the springs, which were not perfectly aligned with the center of gravity of the spacecraft, caused the spacecraft to initially tumble in orbit. After a few days the magnets had locked into the Earth's field, and some of the tumbling inertia was translated into spin about the Z axis. Initial spin rates about the Z axis were about 20 minutes per revolution, tumble rates were apparently much higher. The change from tumble into magnetic lock has not been studied in detail and is of great interest to the spacecraft builders because it provides valuable information concerning the design of spacecraft using this stabilization method.

All of the above motions happened as expected except for the spin direction of PACSAT. PACSAT's spin is discussed in more detail below.

DOVE quickly spun up to a brisk 20 seconds or so per revolution due to its longer downlink antenna blades (see Figure 8 for actual DOVE array current plots). The exact spin rate at this time has not been determined because the real time telemetry sample rate is too slow to assure an accurate measurement. In order to obtain an accurate picture of a wave form, it must be sampled at a rate at least twice its frequency (Nyquist rate). Since the sample rate is 10 seconds and the apparent spin rate was 20 seconds, we believe we were sampling slower than the Nyquist rate, resulting in aliasing, and the result is suspect. However, strip chart recordings of signal strength made by Junior De Castro, PY2BJO, also indicated an apparent spin rate slightly greater than 20 seconds.

There was some pre-launch concern that DOVE would spin so fast that the gyroscopic effect of the spin would overcome the magnetic lock and it would not roll over at the equator. This does not seem to have happened as array current and IR sensor telemetry clearly indicate its +Z surface is up in the northern hemisphere and its -Z surface is up in the southern.

Nutation about the Z axis has been apparent on all spacecraft since magnetic lock was achieved. This is of interest because it affects RF links, has the potential to tell us a great deal about this stabilization method, and affects what can be done with the WEBER camera and other experiments. This nutation can be described as a line extending from the Z axis describing a cone pattern in space, and is sometimes called (reasonably) 'coning'. Initial measurements indicated PACSAT was nutating up to 20 degrees either side of the nominal Z axis alignment, or a total of 40 degrees (see Figure 9 for an early PACSAT array current plot).

The nutation rate was about 56 seconds. That is, a complete circle from say, tilt in the direction of flight, all the way around until tilt was again in the direction of flight, took 56 seconds. Theory holds that the nutation direction will be the same as the spin direction, but this has not been proven with data available at this time. The nutation appears to vary a great deal from orbit to orbit. The early array current wave forms were fairly complex and it now appears that we were seeing a combination of the effects of rotation, nutation and antenna shadowing. LUSAT was also nutating, but somewhat less. WEBER nutation was expected to be of greater amplitude than the others because it has less favorable moments of inertia, however WOD scans have not shown this to be the case. DOVE's nutation amount is currently unknown because the TLM

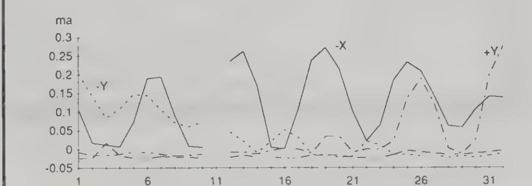


Figure 9 — PACSAT 2-11-90 showing large nutation

sample rate has been too low. The nutation amplitude of PACSAT appears to have reduced since it began to spin up in the correct direction. Nutation amounts of PACSAT and LUSAT now appear to vary from nearly none to about 10 degrees, 20 total. See Figure 10 for an example of PACSAT array currents showing little nutation. The pattern of this variation is not apparent, and the cause is unknown. However, one theory is that the nutation now being seen is caused by the pull of the magnetic poles as the spacecraft passes over the top and bottom of the Earth, but at a point far away from those poles. The effect is similar to giving the top of a spinning gyroscope a push to the side with your finger: a wobble is induced that eventually damps itself out. When the spacecraft orbit passes more directly over the magnetic poles, no nutation is induced because the pull is in line with the orbit plane. At present this is speculation and confirmation will require collection and analysis of additional WOD. It has also been suggested that the variations in nutation are influenced by changes in the Earth's magnetic field and that the spacecraft could be used to study those variations. The nutation amount for PACSAT has been confirmed by correlating the IR sensor data with the array current data (see Figure 11). Plots of both have shown that the Z axis leans over far enough at times that the IR sensor in the +Z sees the sun. Sun angles calculated from the +Z array current match up well with the angle necessary for the IR to be illuminated by the sun.

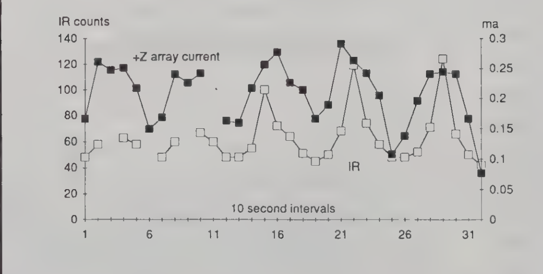


Figure 11 — PACSAT IR and +Z current compensation

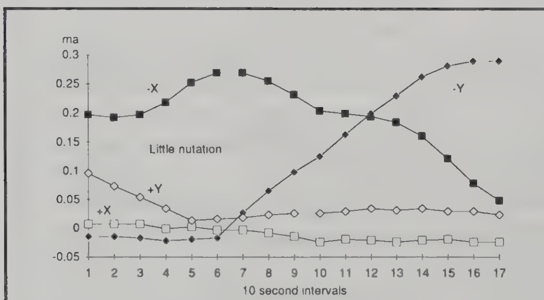


Figure 10 — PACSAT array currents 3-6-90

There was initially some confusion about the spin direction of LUSAT. However, once the opposite orientation of both the turnstile blades and the magnets is taken into account, it is clear that LUSAT spun up in the correct direction.

PACSAT spin reversal

Perhaps one of the most fascinating events related to motion that has occurred since launch was the reversal of the PACSAT spin direction.

Although it had never before been seen in a spacecraft using this stabilization method, there was a 50/50 chance that any one of the Microsats would start out spinning in the 'wrong' direction; that is, the direction opposite that caused by the solar propeller. As it turned out, this is exactly what happened with PACSAT. By early February it was clear it was spinning clockwise instead of counter clockwise, and was slowing down. By the tenth of February it had slowed down to about one revolution per hour, and on about February 17 it turned around and began to spin in the correct direction (see Figures 12 and 13). While enough data has been examined to assure this interpretation is correct, much additional study is necessary to determine exactly when the turn around occurred, if there was any tumbling, if magnetic lock continued even though there was no spin, how long there was little or no spin, etc. PACSAT has continued to spin up and has now reached a rate of about 2 1/2 minutes per revolution, which is well within the design parameters (refer to Figure 14).

The importance of understanding nutation

Understanding nutation is important for a number of reasons. Let's first look at RF link performance. For the purposes of this discussion we will ignore the slight tilt of the Z axis caused by the tilt of the Earth's magnetic field lines. Assume for a moment the Z axis of PACSAT is stable (no nutation) and the orbit will pass directly over your station, which is in the northern hemisphere well away from the magnetic equator. As the spacecraft comes over the horizon the uplink antenna sticking out the top of the spacecraft will be pointed away from you at an angle of about 117 degrees from a line drawn between you and the satellite (see Figure 15a). The downlink turnstile will be pointed at the Earth, but away from you by about 63 degrees. We could say the pointing angle of the downlink antenna is 63 degrees. This angle will slowly decrease as the spacecraft approaches until, when it is directly overhead, the pointing angle will be essentially zero. It will then increase until at the opposite horizon it is again about 63 degrees. On the horizon the polarization of the downlink signal will be elliptical and of the proper handedness and overhead it will be nearly perfectly circular. Note that the handed-

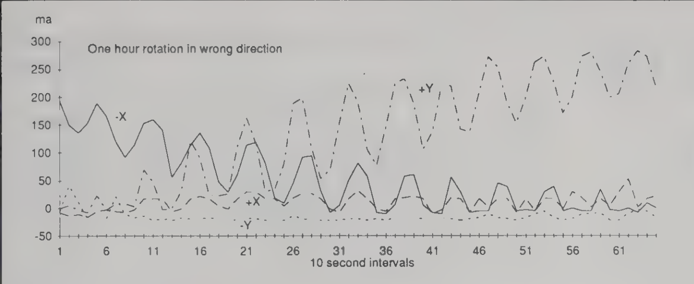
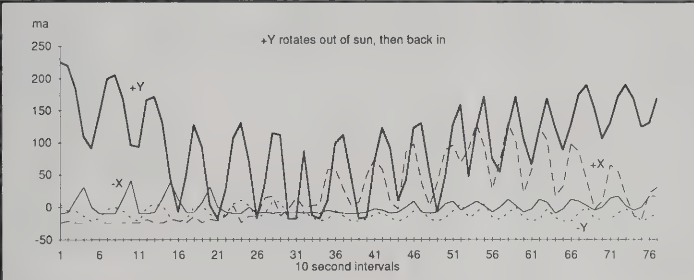


Figure 12 — PACSAT on 2-16-90



Fgure 13 — PACSAT turn around, 2-17-90

ness of the polarization will be left for one transmitter in each spacecraft and right for the other.

If the pass is not directly overhead the initial off pointing will be less, but it will not be zero at time of closest approach (TCA) or highest elevation. For a pass that never gets above 15 degrees elevation, the pointing angle never gets better than about 45 degrees, and the polarization is always elliptical. Of course, for stations near the magnetic equator the situation is quite different since the spacecraft is rolling over 180 degrees at that point.

Now let's assume that the spacecraft has a 40 degree nutation about the Z axis (20 degrees either side of the stable position). Remember that the nutation rate is about 1 minute per rotation. Now when on the horizon, the pointing angle will vary from about 83 degrees to about 43 degrees in 30 seconds (Figure 15b). An 83 degree off pointing will cause the polarization to be nearly linear and at that point in the nutation cycle the polarization would be horizontal. When nutation causes the spacecraft to tilt to the left or right as seen by the observer the polarization would be strongly elliptical and canted about 20 degrees from horizontal.

At this time we do not have radiation pattern measurements from the Microsat

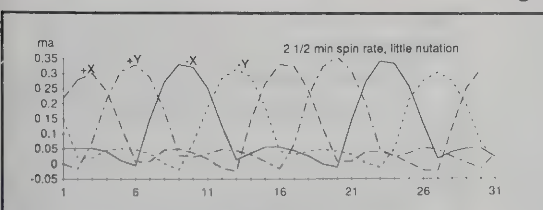


Figure 14 — PACSAT on 4-16-90

antennas, except for the S band antenna. The engineering model may be used to complete that work. However it should be obvious that nutation such as we are seeing will have some effect on RF link performance. This will be especially true when using simple omnidirectional ground station antennas. Remember that nutation is not present on every orbit. Since one of the objectives of the Microsat effort was to demonstrate effective use with simple antennas, and the most efficient simple design is probably going to be influenced by the nutation, so an understanding of nutation is important.

S band performance on DOVE and PACSAT will also be affected by nutation. The S band antenna is a bifilar helix which projects from the +Z surface and is mounted about 1 1/4" in from the edge. That surface is generally away from the Earth in the northern hemisphere, so for high elevation passes in that area the body of the spacecraft is often between the antenna and the ground station. However, when nutation is present the ground station will see a complex pattern of changes in polarization and signal strength as the short nutation period and the longer spin period interact. The design of ground station antennas could be changed to most efficiently work with this pattern once it has been characterized.

It would be advantageous to be able to include the pointing angle of the Microsats in tracking programs. This would help those experimenting with antennas or just using the spacecraft; station adjustments could be made to achieve maximum efficiency. It may turn out, for example, that one type of simple antenna works best when the spacecraft is making a low elevation pass and a different type works well for high elevation passes. It may also be true that different antennas work best for different amounts of nutation. It will be necessary to more fully understand the cause of the nutation in order to mathematically model, and to some extent predict, the spacecraft motion in tracking programs.

Since nutation is generally undesirable and magnitudes this large were not expected, it is important to determine the cause and characteristics of the nutation so the designs of future similar spacecraft can be modified appropriately.

Areas needing further study and investigation

A number of areas of study falling into the general category of motion and stabilization are ripe for further investigation. Some will require research into fields such as antenna radiation patterns, or the application of knowledge of physics, orbital mechanics, etc. Some will also require access to sophisticated test equipment or the Microsat engineering model. Many can be undertaken with only a small amount of assistance from the engineering team. However, for most, all needed data can be obtained from Microsat telemetry and published documents. The following is a summary (in no particular order) of those study areas. It is not exhaustive, but is included here in an attempt to show the richness of further investigative opportunities, and in the hope that it will stimulate those interested in Amateur satellites, or just in satellites, to participate in this fascinating field.

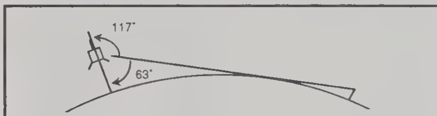


Figure 15a — Pointing angle, no nutation

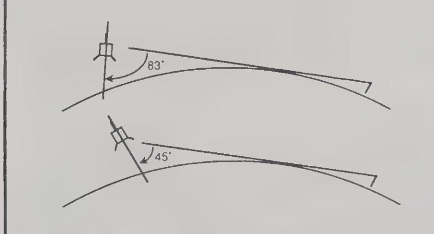


Figure 15b — Pointing angle with nutation

• Exactly when and why does a Microsat's Z axis wobble? What is the cause of the nutation? Can we understand enough about the cause to predict when it will occur and what its amplitude will be? There is a component of precession in the roll over that occurs at the equator. Exactly how much does the Z axis deviate from the orbit plane during this event?

• What is the nature of WEBER wobble as compared to the others? WEBER's moments of inertia are different. How does that affect its susceptibility to nutation? Given verification of proper operation, can WEBER nutation be correlated to its magnetometer readings to validate those readings, or the other way around? Can the magnetometer readings be correlated to the array currents?

(Continued on page 30)

The Telemetry Formats of JAS-1b/Fuji-OSCAR 20

Compiled by
JR1NVU
J.A.R.L / JJ1ZUT FO-20 Control Station

Telemetry data from FO-20 is transmitted on both Mode JA and JD beacons. Mode JA sends data by Morse code on the beacon signal of 435.795 MHz, repeating one frame every one minute. Mode JD sends a telemetry packet every 2 seconds on the digital downlink channel of 435.91 MHz when the telemetry mode is operating, otherwise, one frame is downlinked every one minute. This article contains the information you need to decode the telemetry. The spacecraft can downlink up to 30 items of data and 31 items of status in the telemetry. The Mode JA beacon however only carries 12 data elements and most of the status bytes.

Table 1 — CW Telemetry data frame format

HI	HI	1A	1B	1C	1D
		2A	2B	2C	2D
		3A	3B	3C	3D
		4A	4B	4C	4D
		5A	5B	5C	5D

Mode JA Telemetry Data

The Mode JA beacon transmits the telemetry data in the format shown in Table 1. These data are sent by Morse code with a "HI HI" at the beginning of each frame, with a speed of about 100 characters every minute, and always in this format repeatedly.

How to decode Mode JA telemetry

Table 1 shows the format of a telemetry frame from the JA beacon. The number identifies the group, the letters A through D are decimal values expressed in two digits. Let this two-digit be N, for each item, the true value or engineering value is obtained by decoding N as shown in Table 2. For example, a value of 123 for 1A means group 1 and 23 is the measured value of the solar array current. Groups 4 and 5 contain status information about the bird, where A, B, C and D represent octal two-digit combinations of 00 through 37. This corresponds to a combination of five binary digits. Each bit shows status of each designated item in the order from MSB (Most Significant Bit) to LSB (Least Significant Bit).

The status byte conversions are shown in Table 3. This method is used because all items whose status is represented in this manner only have two possible situations, either ON or OFF, or binary values 0 or 1. For example, if the first item of status 4A were 423, the 4 identifies group 4, and the 23 should be thought of as its equivalent binary code (10011). This shows the status in the order of MSB to LSB, or bit 4 to bit 0. Using the data in Table 3, 423 can be decoded as follows.

1: Beacon is PSK, 0: Engineering data #2 is blank, 0: Engineering data #1 is blank, 1: JTD power is ON, 1: JTA power is ON.

Mode JD Telemetry Data

Telemetry data are also sent on Mode JD by means of packets.These data are transmitted the ASCII format shown in Table 4. In the ASCII telemetry (RA and SA) XXX is a 3 digit decimal number with a a range between 000 to 999. This number represents the value of N in Table 5 for channels denoted #00 - #26.

Table 2. Mode JA Telemetry Conversion Equations

CH	*DESCRIPTION*	*CALIBRATION*
1A	total solar array current	19x(N+0.4) mA
1B	battery charge/discharge current	-38x(N-50) mA
1C	battery voltage	(N+4)x0.22 V
1D	center tap voltage of battery	(N+4)x0.1 V
2A	bus voltage	(N+4)x0.2 V
2B	+5 V regulator voltage	(N+4)x0.062 V
2C	JTA output power	2.0x(N+4)^1.618mW
2D	calibration voltage	(N+4)/50 V
3A	battery temperature	1.4x(67-N) deg. C
3B	baseplate temperature #1	1.4x(67-N) deg. C
3C	baseplate temperature #2	1.4x(67-N) deg. C
3D	baseplate temperature #3	1.4x(67-N) deg. C

Table 5 contains the equations for converting the received data into engineering values. The YYY bytes are three hexadecimal bytes of system status data, denoted #27a - #29c and can be decoded as shown in Table 6. The SSS byte in the last row are binary status data, denoted #30a - #39c. Table 7 provides the information needed to decode them in a manner similar to the Mode JA status points shown in Table 3.

A quick glance at the sample frame in Table 4-2 shows that it was transmitted when Fuji-OSCAR 20 was in sunlight.

Table 3 — Mode JA System Status Bytes

CH	*BIT*	*DESCRIPTION*	*STATE* 1	0
4A	0	JTA power	ON	OFF
4A	1	JTD power	ON	OFF
4A	2	Eng. data #1	—	—
4A	3	Eng. data #3	—	—
4A	4	Beacon	PSK	CW
4B	0	UVC	ON	OFF
4B	1	UVC level	1	2
4B	2	Battery	tric	full
4B	3	Battery logic	tric	full
4B	4	Main relay	ON	OFF
4C	0	PCU	bit 1	(LSB)
4C	1	PCU	bit 2	(LSB)
4C	2	PCU	manual	auto
4C	3	Eng. data #3	—	—
4C	4	Eng. data #4	—	—
4D	0	Memory bank #0	ON	OFF
4D	1	Memory bank #1	ON	OFF
4D	2	Memory bank #2	ON	OFF
4D	3	Memory bank #3	ON	OFF
4D	4	Computer power	ON	OFF
5A	0	Memory select	bit 1	(LSB)
5A	1	Memory select	bit 2	(MSB)
5A	2	Eng. data #5	—	—
5A	3	Eng. data #6	—	—
5A	4	Eng. data #7	—	—
5B	0	Solar panel #1	lit	dark
5B	1	Solar panel #2	lit	dark
5B	2	Solar panel #3	lit	dark
5B	3	Solar panel #4	lit	dark
5B	4	Solar panel #5	lit	dark
5C	0	JTA CW beacon	CPU	TLM
5C	1	Eng. data #8	—	—
5C	2	Eng. data #9	—	—
5C	3	Eng. data #10	—	—
5C	4	Eng. data #11	—	—
5D	0	Eng. data #12	—	—
5D	1	Eng. data #13	—	—
5D	2	Eng. data #14	—	—
5D	3	Eng. data #15	—	—
5D	4	Eng. data #16	—	—

Don't forget to Register in Advance for the AMSAT Symposium and Annual Meeting! See p. 29

Table 4-1 Mode JD PSK telemetry data format

JAS-1b FF YY/MM/DD HH:MM:SS
XXX XXX XXX XXX XXX XXX XXX XXX XXX XXX
XXX XXX XXX XXX XXX XXX XXX XXX XXX XXX
XXX XXX XXX XXX XXX XXX XXX YYY YYY YYY
SSS SSS SSS SSS SSS SSS SSS SSS SSS SSS

where, FF is the Frame Identifier, which may contain the following types:
RA: Realtime telemetry, - ASCII
RB: Realtime telemetry, - Binary
SA: Stored telemetry, - ASCII
SB: Stored telemetry, - Binary
M0: Message #0
M1: Message #1
....
M9: Message #9

YY/MM/DD is year/month/day, and
HH:MM:SS is hour/minute/second, all in UTC

Table 4-2 Actual sample of Mode JD PSK telemetry data as copied by KI6QE

19-Apr-90 17:14:34 8J1JBS*>BEACON:
JAS1b RA 90/04/19 17:13:58
609 430 687 676 744 837 845 829 498 681
617 001 505 516 526 524 526 523 654 000
683 675 686 695 999 643 875 471 099 000
110 111 000 000 111 100 001 111 111 000

Table 7 — Mode JD BINARY System Status Bytes

CH	*DESCRIPTION*	*STATE*	
#30a	JTA power	on	off
#30b	JTD power	on	off
#30c	JTA beacon	PSK	CW
#31a	UVC status	on	off
#31b	UVC level	1	2
#31c	main relay	on	off
#32a	eng. data #1	——	
#32b	battery status	tric	full
#32c	battery logic	tric	full
#33a	eng. data #2	——	
#33b	PCU status	bit 1	(LSB)
#33c	PCU status	bit 2	(MSB)
#34a	memory unit #0	on	off
#34b	memory unit #1	on	off
#34c	memory unit #2	on	off
#35a	memory unit	on	off
#35b	memory select	bit 1	(LSB)
#35c	memory select	bit 2	(MSB)
#36a	eng. data #3	———	
#36b	eng. data #4	———	
#36c	computer power	on	off
#37a	eng. data #5	———	
#37b	solar panel #1	lit	dark
#37c	solar panel #2	lit	dark
#38a	solar panel #3	lit	dark
#38b	solar panel #4	lit	dark
#38c	solar panel #5	lit	dark
#39a	eng. data #6	———	
#39b	CW beacon source	CPU	TLM
#39c	eng. data #7	———	

Table 5 — Mode JD Telemetry Decoding Equations

CH	*DESCRIPTION*	*CALIBRATION*
#00	total solar array current	1.91x(N-4)mA
#01	battery charge/discharge	-3.81x(N-508)mA
#02	battery voltage	Nx0.022V
#03	battery center voltage	Nx0.009961V
#04	bus voltage	Nx0.02021 V
#05	+5 V regulator voltage	Nx0.00620 V
#06	-5 V regulator voltage	-Nx0.00620 V
#07	+ 10 V regulator voltage	Nx0.0126 V
#08	JTA output power	5.1x(N-158)mW
#09	JTD output power	5.4x(N-116)mW
#10	calibration voltage #2	N/500 V
#11	offset voltage #1	N/500 V
#12	battery temperature	0.139x(669-N)deg. C
#13	JTD temperature	0.139x(669-N)deg. C
#14	Temperature #1	0.139x(669-N)deg. C
#15	Baseplate Temperature #2	0.139x(669-N)deg. C
#16	Baseplate Temperature #3	0.139x(669-N)deg. C
#17	Baseplate Temperature #4	0.139x(669-N)deg. C
#18	temperature calibration #1	N/500 V
#19	offset voltage #2	N/500 V
#20	Solar Cell Panel Temp #1	0.38x(N-685)deg. C
#21	Solar Cell Panel Temp #2	0.38x(N-643)
#22	Solar Cell Panel Temp #3	0.38x(N-646)
#23	Solar Cell Panel Temp #4	0.38x(N-647)
#24	————————	
#25	temperature calibration #2	N/500 V
#26	temperature calibration #3	N/500 V

Table 6 — Mode JD HEX System Status Bytes

CH	*DESCRIPTION*
#27a	Spare (TBD)
#27b	Spare (TBD)
#27c	Spare (TBD)
#28a	Spare (TBD)
#28b	Spare (TBD)
#28c	error count of memory unit #0
#29a	error count of memory unit #1
#29b	error count of memory unit #2
#29c	error count of memory unit #3

SAREX - The Saga Continues

A Letter from W6GO:

(Continued from page 3)

to communicate with the rest of the Amateur community?

2. My message is incompletely quoted in the *AMSAT Journal*. The message was sent out as a query, not a directive. The last paragraph was left off in the *Journal*. It was only one sentence. One sentence that if left off, changes the meaning of my entire message (IT WAS NOT A NOTE). The sentence left off by AMSAT was:

"Your thoughts?"

Look at page 11 of that issue in the *Journal*. Reread my message to ALL and add this question to the end. Sounds different, doesn't it?

3. My message quoted by AMSAT was not sent as a response to a note circulated by Tom Clark (whomever he is), as implied in the article. My message was self-initiated. It was not sent originally as a response to anyone.

If Mr. Clark wishes to send me a copy of whatever it was that I supposedly responded to with my message, I will be very happy to respond to his query. This time, however, W3IWI will be very well aware that I am replying to HIM. There will be no need for him to pick up the telephone and ask me if my message to "ALL" really was a response to him. I will make it very clear. He will be able to quote my response as being a response to W3IWI, not to ALL.

4. Ray Soifer, W2RS, referring to my message, says the message was sent to PacketCluster SYSOPs, somehow "advising them to stay on 144.95". The message quoted above asked questions, it didn't give advice. Mr. Soifer, I really would like to know exactly how you can read your statement that I "advised them to stay on 144.95" into this message.

Yes, in other correspondence I have suggested that we stay on 144.95, because there really is no way we can shut off hundreds of users for ten minutes at a time. Here in Northern California the Northern California Packet Association (NCPA) is attempting to get us a temporary frequency for the duration of the mission. We plan to move to that frequency if possible, even to the point of placing rush crystal orders for the many mountain top digipeaters and commercial crystal-controlled radios in use on the nodes. WE ARE NOT FREQUENCY AGILE like SAREX. If we can successfully move, then our users will move with us. If we shut down the nodes for SAREX passes, the users stations will continually attempt connects to our nodes, resulting in more interference to SAREX then if we merely stayed on the air with our users connected.

5. W2RS says he has been in touch with the local PacketCluster and the SAREX bulletins have been posted on the Cluster. I guess that W2RS thinks that will somehow have the effect of shutting down the users of

PacketCluster, especially those who only get DX reports and don't read the bulletins. Most of the users of the DX PacketClusters here just leave their radio connected for months at a time. They merely read the screen, and occasionally announce a DX station. They have no reason to read bulletins, and would probably not read one titled "AMSAT", "SAREX" and maybe not even one titled "ARRL". If the bulletin said "ZA operation next week", they would read it.

6. W2RS encourages deliberate QRM, advising "Your signal should override those from the packet clusters with few problems". Problems to whom? Certainly not "few problems" to the PacketCluster users! PacketCluster users are going to be blown away by those who listen to W2RS! The Webster's definition of "override", the word used as W2RS's advice to prospective SAREX connectees, includes the words TRAMPLE, DOMINATE, PREVAIL, and ANNUL. Is this AMSAT's policy of what to do to licensed Amateurs who don't happen to be interested in space communication?

By the way, check it out. My old call, W6GDO, was reported heard through OSCAR 4 more times than any other call sign. I've been there, folks. I duplexed when no one else was duplexing. But, my interest now is HF DXing, and the DX PacketCluster is a tool for me just like your satellite tracking programs are tools for you. We should both be able to enjoy our parts of this wonderful hobby, but we both need to be concerned about the other guy! TRAMPLE, DOMINATE, PREVAIL, ANNUL. Look it up.

7. W2RS admits that if the PacketClusters were on 145.55, there "WOULD be a problem". One of the spokesmen for the TCP/IP group who uses 145.55 in Northern California has suggested to me that we swap frequencies for the SAREX duration. Maybe we should? No chance, I'm not LOOKING for trouble. I'm just trying as hard as I can to get some people to see that they are not alone in this world, and certainly not alone on 144.95.

8. W3IWI somehow tries to invoke squatters rights, implying that a use many years ago with no intervening activity between then and now constitutes frequency coordination for evermore. Boy, is Mr. Clark out of touch with reality. In this day and age, you have to keep using a frequency to maintain whatever "rights" you may have. And if you don't think we are using 144.95, you aren't listening. My node alone makes over two million transmissions a year on 144.95. Add three million for the users and the digipeaters, and then multiply that by the 60 in the USA on 144.95 MHz. That's THREE HUNDRED MILLION transmissions a year! How many transmissions have YOU made on 144.95 since the last space use of that frequency, Mr. Clark?

Squatters rights. Interesting you should say "squatter", because Webster defines a squatter as "One that settles on property without right or title or payment of rent". The second definition is "One that settles on public land under government regulation with the purpose of acquiring title". Neither fits AMSAT, because AMSAT doesn't meet the definition of "settles". You look it up. We have settled 144.95. Colonized it, established residence, secured permanently, and "taken up an ordered or stable life". Remember, you invoked the squatters rights issue, not me.

9. Adjacent to the article in the July *AMSAT Journal* is a table of proposed times and operating schedules for the SAREX mission, including times for "SAREX robot", "Post-sleep", "Pre-sleep", etc. It is credited to W3XO and WA4SIR.

When I talked to W3XO on the telephone when the shuttle was on the launch pad (he was at NASA in Texas), he told me that he would be sending me copies of all of the SAREX plans and schedules. He told me that he would see to it that PacketCluster was represented. He told me that he would keep in contact with me.

He told me that the real problem was with ARRL, as AMSAT had queried ARRL on the frequencies and ARRL told AMSAT to go ahead. He said he was not aware of ANY activity ANYWHERE on 144.95, and that the league had plenty of opportunity to bring 144.95 activity to AMSAT's attention. I have sent W3XO copies of ALL of my correspondence. I have heard NOTHING from W3XO, who, by the way, writes the VHF/UHF column in *QST* magazine. NOTHING. ZIP.

10. Another adjacent article, of which I can only read part due to the fact that I received only a one-page fax, explains how to connect to the SAREX ROBOT. It supports the stories I heard from Eastern USA SYSOPs who told me of the deliberate QRM they received on 144.95 while SAREX was on the launch pad.

The stories are about people transmitting connect WA4SIR packets every five seconds for hours on end, blowing the PacketCluster users away. Supposedly listening on 145.55, but ONLY for a response from WA4SIR! Absolutely NOT listening on their transmit frequency. One of the offenders was contacted. He told the SYSOP that they were going to blow the PacketCluster right off the frequency, and that PacketCluster and all of its users should move NOW. That SYSOP plans to file a

formal complaint with the FCC the next time the offender transmits on 144.95, SAREX or not. War has been declared in at least one area.

The jammer pointed out that he was only doing exactly what ARRL and AMSAT told him to do. Transmit on 144.95 and listen only on 145.55, and, at that, only accept signals from WA4SIR!

The positive part of the myopic article in the *AMSAT Journal* is that at long-last we are finally identified. Sure, identified as trouble-makers rather than as people trying to call attention to future problems that can be mitigated with an effort put forth on everyone's part, but nonetheless identified. Now that AMSAT admits we exist, maybe we can establish some dialog and find ways to satisfy everyone's needs. Your Editor has given me some hope that this may be possible.

Conclusion

I'm told that the shuttle really has three 600 kHz split frequency pairs available, plus many combinations of non-600 kHz split pairs. Maybe the folks on the other two 600 kHz channels would like one-third of SAREX? We will be glad to share.

I cannot understand why SAREX must operate outside the "Space frequencies". W3XO told me that one reason is that FM was not desired in the space frequencies. All I know is that if I accidentally wander into the OSCAR band, I'm firmly advised that I should move and observe the Space Window". I move as suggested. However, now I suspect hypocrisy on the part of AMSAT. Maybe we should move PacketCluster up into the OSCAR band?

On the subject of hypocrisy, I find it somewhat incredulous to accept the ARRL as QSL manager for a DX-pedition that transmits on one frequency and listens only on a well-established net frequency, encouraging people who contact the DX-pedition to not even bother listening where they are transmitting. The ARRL editorializes that DX-peditions should use and observe the "DX-Windows". But if they are in space, I guess there is no reason to observe the "Space Window".

OK, AMSAT, there may be no way to make any changes for the upcoming flight. OK, we will do our best to help, but you have to understand our circumstances too! However, NOW IS THE TIME TO DO SOMETHING FOR THE NOVEMBER MISSION! W5DID, who programs the SAREX Radio, tells me that he can accommodate frequency changes (from AMSAT) up until September first. The ARRL is sitting on its hands, just letting this window of opportunity pass. You, however, can do something!

Thank you for providing this opportunity for me to respond.

73, Jay O'Brien, W6GO, P.O. Box 700, Rio Linda, CA 95673. 916 991-2101 (res); 916 991-1000 (fax); 916 002-0923 (DX-BBS); 916 991-7263 (bus)

Editor's comment:

The 144-146.00 MHz band is used in different ways in different parts of the world. 145.55 MHz was picked because it was used for FM everywhere. WA4SIR will downlink on 145.55 MHz and listen on 144.95 MHz. Yes this uplink frequency is shared with terrestrial users, and yes there is a tremendous potential for QRM to stations operating on that frequency who are not interested in working WA4SIR.

Packet radio, being computer intensive allows the capability for automatic legal unattended operation on 2 Meters. It is possible to set up a situation in which a

station can try to connect to WA4SIR for long periods of time. I don't want to state how, after all, if people don't know how, far be it from me to give them ideas.

Anyone who is observed trying to connect to WA4SIR more than 10 minutes before AOS or more than 10 minutes after LOS at any location (on the 144.95 MHz frequency) may be considered as causing QRM to other services on that channel. **Should such situations arise, I'm willing to publish well documented instances in the *AMSAT Journal* including call signs of the stations involved and further, request that the WA4SIR QSL be withheld.**

We have an exclusive satellite section of the 2 Meter Band. For valid reasons we are not using it for the SAREX flight. Remember that we share the Robot frequencies with FM and terrestrial packet services. Please minimize the QRM, remember this is not 20 Meters. — *Joe, W3/G3ZCZ*

Need a Standard?

With DOVE and UoSAT 3 sending TLM packets and then FO-20 sending still different TLM. BOY!! Oh BOY!! How do you keep up?

I, for one, agree with your article. We NEED a standard.

73, Syd, W2ICZ@W2SEX

1990 Dayton Hamvention Award

I wish to thank you and other Amateur Radio media for the recent publicity concerning the award I was given at the 1990 Dayton Hamvention. It is an honor to have one's efforts rewarded by such a prestigious organization and for the multitude of media in ham radio today to recognize this work. However, I believe the reporting has been incomplete. The reporting in general made it appear (to me anyway) that Microsat was an N4HY enterprise. Nothing could be further from the truth. I played an important, possibly crucial role, in the Microsat project. I did help manage the project during an awkward time and did in fact make major contributions to the satellite hardware and software. I managed the final construction of the CPU (based on a good design by Lyle Johnson, WA7GXD, that was exceedingly difficult to manufacture in the space allotted) by inducing (former?) friends of mine, who believed in the project to sacrifice many hours of time, expertise, valuable resources, and to demand innumerable favors to complete the computers. It must be said however that the satellites are a testament to ALL of the people who participated in the project. I am proud to have worked with a group comprised of people from AMSAT, TAPR, ARRL Labs, BRAMSAT, AMSAT-LU, Weber State University, and others. Had the Dayton Hamvention nomination been based solely on Microsat, or had the award been based solely on Microsat, I would have refused it as unfair and unjustified. In fact, the award was based on my participation and contributions to some of the best projects in Amateur Radio today. The joint work with W3IWI and WA7GXD on digital signal processing software and hardware for TAPR and AMSAT, with KB2CST, KA2MOV, and AEA on a new DSP based multimode controller unveiled at Dayton this year, the satellite tracking program known as Quiktrak, DOVE hardware, command/control software for all the Microsats, etc. were the basis for the nomination for this award. I feel uniquely blessed to have played a part in these outstanding projects. I wish to share the honor bestowed on me by the Dayton Hamvention with others who have worked with me on the myriad projects I am or have been a part of and which were the premise for the award nomination.

Let me tread on hazardous ground and render a personal opinion on the Microsat project and probably get myself into trouble at the same time, HI! My opinion is that there were four unique pieces of this project that made it glue together and work. W3GEY, Jan King, and Dick Jansson, WD4FAB, came up with the modular mechanical structure and solar panel design which provided the impetus for the entire project. The mechanical structure has been copied now by other satellites of recent vintage because of the beauty, simplicity, and agility of the structure for spacecraft design. Second: Tom Clark, W3IWI, gave us the concept and initial design for a local area network and electrical bus for the spacecraft electronics which enabled the development work for the individual modules comprising the spacecraft to be done by people geographically separated by great distances. I give but one example. AMSAT-LU designed a CW beacon experiment for LUSAT, LO-19. This experiment was built in Argentina, placed in a module, and interfaced to the rest of the spacecraft by the local area net and bus design done by W3IWI and implemented by Bob Stricklin, N5BRG. This module had never 'seen' the other modules in the spacecraft before and worked perfectly when placed in the spacecraft on the first try. This experience was repeated several times in all four spacecraft. Third: Given all this hardware, you have to have software to run a spacecraft designed around a computer. Harold Price, NK6K, induced Quadron, Inc., a company he helped found, into giving us a modified version of the their multitasking kernel (operating system and written by Harold) for use on the Microsats for Amateur Radio satellite projects. It is not unlike having a (good) DOS and it has allowed us to use standard PC-clone software development tools to write the applications needed to run the spacecraft. This modularity, in terms of structure, electronics, and software are what made Microsat possible. The fourth and final piece that I consider vital, cannot and should not be underestimated. It is the many people who made major efforts to bring these ideas together into satellites. It never ceases to amaze me that Amateur Radio in general and AMSAT in particular, always succeeds in getting people to make personal sacrifices that are completely unthinkable when these projects are started, in order that they may succeed. These sacrifices are of a nature that would almost never be seen by people in their regular work and indeed are often made at a cost of loss of 'domestic tranquility'. The people of the Microsat team will never be adequately thanked but I would like to express my personal thanks here. I am extremely proud of the work WE accomplished. The work in making the complete facilities afforded by these satellites available to Amateur Radio continues and we are beginning to plan our satellite building future here in AMSAT-NA and with our traditional international satellite building partners. Why don't you come join us? See you on the birds! — *Bob McGwier, N4HY*

Software for Decoding AMSAT-OSCAR 13 Telemetry

A program is available from Project Oscar for a donation of at least $20 that decodes and displays the AMSAT-OSCAR 13 RTTY Telemetry. The program is available for both the IBM PC compatible computer (with DOS 2.2 or later and BASIC A interpreter) or an Apple II series computer (with 64K memory, 80 column card, PRODOS and BASIC.SYSTEM programs),

All you need supply in addition, is an ASCII file editor (found in many modem terminal programs and word processors); a modem capable of copying 170-200 Hz shift RTTY at 45-50 baud; and a 2m and/or 70 cm SSB receiver.

You first copy the RTTY telemetry from the AMSAT-OSCAR 13 beacon and save it to disk as an ASCII file. You then edit this file using the ASCII file editor to delete everything except the numeric telemetry block which will be read and decoded by

Table 1 — A typical example of AMSAT-OSCAR-13 RTTY Telemetry available from Project OSCAR, Inc.

```
AO-13 TELEMETRY DATA FOR OCT. 17, 1989 AT 19.00.34 UTC, ORBIT # 1030:
SAFETY FLAGS: NONE
COMMUNICATIONS SYSTEMS:
TRANSPONDER STATUS: PASSBAND ON,  +14 V BUS CURRENT = 2839 MA
ANTENNAS ON LINE  : 2 M HIGH GAIN,  70 CM HIGH GAIN
MODE B : 2 M TX OUTPUT = 0 WATTS,  TX AMP TEMP = 17 C
         70 CM RX AGC = 1 DB,  RX TEMP = 21 C
         TRANSPONDER +9 V SUPPLY = 0 MV
MODE JL: 70 CM TX OUTPUT = 12 WATTS,  TX AMP TEMP = 38 C
MODE L : 24 CM RX AGC = 11 DB,  RX TEMP = 19 C
         TRANSPONDER +9 V SUPPLY = 9125 MV
MODE S : TX OFF, BEACON OFF   SQUELCH CLOSED, SENSE HIGH   TEMP = 6 C
RUDAK  : ON, NO GROUND STATION LOCK, STANDARD OPERATING SYSTEM  TEMP = 15 C

ELECTRICAL POWER SYSTEMS:

SOLAR CELL PANELS (ARMS):
   1 = 0 MA, 2 = 718 MA, 3 = 0 MA, 4 = 0 MA, 5 = 0 MA, 6 = 189 MA
   SOLAR PANELS OUT (BCR INPUT) = 30394 MV
BATTERY CHARGE REGULATOR (BCR) OPERATION:
   BCR OSC #1 ON LINE    OSC #2 OFF   BCR TEMP = 22 C
   BATTERY STATUS,  MAIN CONNECTED,  AUX DISCONNECTED
   BCR OUTPUT (MAIN BATTERY) = 13594 MV  AT 2645 MA
   AUX BATTERY VOLTAGE = 314 MV
   BATTERY CHARGE CURRENT = 0 MA
   BATTERY TEMP,  MAIN = 18 C,  AUX #1 = 14 C,  AUX #2 = 18 C
   KNEE VOLTAGE SETPOINTS,  BATTERY = 4394 MV,  ARRAY = 1629 MV
+10 VOLT REGULATOR  = 10054 MV AT 63 MA  (COMPUTER SYSTEMS)
+14 VOLT REGULATOR  = 13493 MV

SPACECRAFT STATUS:
SPIN RATE (Z AXIS) = 29 RPM
MAGNETORQUERS AND ANTENNA RELAY +14 V BUS CURRENT = 24 MA
EARTH SENSOR SENSITIVITY THRESHOLD = 1.2 V
SERI LIGHT SENSORS: LOAD RESISTORS = 3.9 OHMS
                    TOP (ANT) +Z = 8 MA, BOTTOM (MOTOR) -Z = 102 MA
COMMAND NUMBER COUNT    = 242
MEMORY SOFT ERROR COUNT = 7
ARM 1: SOLAR PANEL 1 = 9 C  WALL = 17 C  SKIN TOP = 4 C, BOTTOM = 24 C
       2 M TX AMP = 17 C   70 CM TX AMP = 38 C   70 CM RX = 21 C
       24 CM RX = 19 C   MODE S XPONDER = 6 C
ARM 2: SOLAR PANEL 3 = 8 C   WALL = 11 C   +Z SERI PLATFORM = 2 C
       SENSOR ELECTRONIC UNIT = 15 C   AUX BATTERIES #1 = 14 C,  #2 = 18 C
       BCR = 22 C
ARM 3: SOLAR PANEL 5 = 9 C   HELIUM TANK = 14 C   MAIN BATTERY = 18 C
       RUDAK = 15 C   IHU (COMPUTER) = 14 C   NUTATION DAMPER = 12 C
CENTRAL BODY: FUEL TANKS, TOP (N2O4) = 16 C   BOTTOM (AZ50) = 19 C
```

the Project OSCAR program. A typical example of coded AMSAT-OSCAR 13 RTTY Telemetry is shown in Table 1 (previous page).

Every decimal, hexidecimal, and bit sent in the RTTY block that contains information is decoded (except for the now inoperative rocket motor control data which is assigned variables but not decoded).

Information is clearly presented in four parts: safety flags, communication systems, electrical power systems, spacecraft status.

The program is written in BASIC and is heavily "remarked" (documented and referenced), making it easy to understand what is being done and easy to modify if desired.

The program has been "crash proofed" with error trapping that tells you if something is wrong and how to correct it.

Information was obtained from AMSAT-OSCAR 13 control stations VK5AGR, DB2OS and KØRZ that corrects any errors previously published and includes the first three lines of hexadecimal and binary bit information not previously explained in North America.

Output can be sent to your computer screen or printer.

A copy of this program is available from Project Oscar (P.O. Box 1136, Los Altos Ca. 94023-1136) for a donation of at least $20. Make your check payable to Project Oscar. All funds received for the sale of this program will be allocated to the development of future Amateur Radio Satellites and not for profit. —*Howard Sodja, W6SHP @ WD6CMU*

AMSAT News

Pakistan Launches Satellite in 2 Meter Band

SUPARCO, a Pakistan government agency, has built and launched that country's first satellite, BADR-1, which was placed into orbit from China at 0050 UTC on July 16, 1990. BADR-1 is transmitting in the Amateur 2 meter band at 145.825 and 144.028 MHz and is in a low Earth orbit with an initial perigee of 210 km and an initial apogee of 992 km. If current predictions hold, BADR-1 will decay into the atmosphere before the end of 1990, probably in October or November.

According to a SUPARCO press release received at the University of Surrey, the objectives of BADR-1 are (i) to test the performance of Pakistan-developed satellite sub-systems in a space environment, (ii) to perform experiments in real-time voice data communications between two user ground stations, (iii) to demonstrate store-and-forward type message communication, and (iv) to educate Pakistan's academic, scientific and Amateur communities in the tracking and use of LEO satellites.

Telemetry has been received from BADR-1 in a format compatible with that of UoSAT-OSCAR 11 (UoSAT 2). BADR-1 is also said to have a store-and-forward Digital Communication Experiment (DCE) and a digitalker like those on the British satellite.

While meeting in Surrey at the Fifth AMSAT-UK/University of Surrey Colloquium, the AMSAT-NA representatives present (including yours truly) joined in sending a message of congratulations from the worldwide AMSAT gathering to SUPARCO on their achievement of building and launching a satellite. Some problems, however, have arisen with respect to the downlink frequencies. The 145.825 MHz downlink has already resulted in QRM to DOVE and UoSAT-OSCAR 11 operations, while that at

144.028 MHz is in a region of the band used primarily for moon bounce communication with extremely weak portable and expedition stations which often have limited operating time and scant lunar access.

The 2 meter band is very crowded and frequencies must be chosen with great care. At the Fourth Surrey Colloquium in 1989, an international mechanism was established through which groups planning Amateur Radio satellites can coordinate their choice of frequencies in all Amateur satellite service bands. AMSAT-UK acts as the secretariat for this effort. We hope that future Amateur-band satellite programs from Pakistan and other new entrants to the "satellite builders club" will avail themselves of this facility, which will also assist in our vital task of preparing for WARC-92.

AMSAT-NA will include BADR-1 in the orbital elements published in the *Journal* and distributed via over-the-air bulletins. — *W2RS*

Congratulations to N5BF & WD5EHM

AMSAT Congratulates Courtney and Viann Duncan (N5BF and WD5EHM) on the birth of a son, John Courtney. He arrived about a month early (right after lunch on Tuesday, August 7, 1990) but, along with mom, two big sisters, and dad, he is doing just fine. Frequencies, modes, and calls will be announced at a later date.

Satellite Orbital Elements

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AO-10
1 14129U 83 58  B 90214.35315139 -.00000030  00000-0  00000 0 0  5402
2 14129  26.0318 191.7033 5957883 164.3697 228.0613  2.05880529 25686
UO-11
1 14781U 84 21  B 90217.58851262  .00001031  00000-0  19855-3 0  7648
2 14781  97.9470 268.5243 0013822  90.2140 270.0664 14.65532084343206
RS-10/11
1 18129U 87 54  A 90220.01480443  .00000007  00000-0  17081-5 0  2804
2 18129  82.9275 290.2393 0011366 342.8542  17.2221 13.72100849156551
AO-13
1 19216U 88 51  B 90216.89332159 -.00000150  00000-0  99999-4 0  1436
2 19216  56.9610 142.4159 7002982 232.8606  40.9111  2.09704479 16420
FO-20
1 20479U 90 13  B 90210.11254104 -.00000005  00000-0  16953-4 0   956
2 20479  99.0366 248.7026 0540669 313.6564  42.0895 12.83157781 22122
UO-14
1 20437U 90  5  B 90217.48134309  .00000542  00000-0  23141-3 0  1910
2 20437  98.6960 293.4444 0011079  16.9807 343.1756 14.28671144 27900
AO-16
1 20439U 90  5  D 90216.48713632  .00000308  00000-0  13886-3 0  1008
2 20439  98.7027 292.5808 0012043  19.3986 340.7653 14.28772947 27764
DO-17
1 20440U 90  5  E 90220.05303184  .00000289  00000-0  13104-3 0  1062
2 20440  98.7019 296.1506 0012040   9.1913 350.9485 14.28823511 28273
WO-18
1 20441U 90  5  F 90216.46753124  .00000305  00000-0  13651-3 0  1028
2 20441  98.7019 292.5978 0012584  20.6289 339.5398 14.28915770 27762
LO-19
1 20442U 90  5  G 90218.48878346  .00000448  00000-0  19300-3 0  1033
2 20442  98.7026 294.6374 0012998  13.9090 346.2448 14.28986138 28058
SALYUT 7
1 13138U 82 33  A 90220.00205076  .00036301  00000-0  32777-3 0  4262
2 13138  51.6005  41.1037 0000978 140.8461 219.2588 15.67764204472975
MIR
1 16609U 86 17  A 90219.94806060  .00025600  00000-0  26903-3 0  8476
2 16609  51.6123  69.2112 0010175 234.0492 125.9740 15.64096805256196
HUBBLE
1 20580U 90 37  B 90219.52997041  .00001973  00000-0  21133-3 0  1683
2 20580  28.4694 282.9096 0005766 297.5192  62.4788 14.84695614 15611
NOAA-9
1 15427U 84123  A 90219.19191715  .00000343  00000-0  20634-3 0  6100
2 15427  99.1702 220.2117 0014544 223.1659 136.8371 14.12631318291180
NOAA-10
1 16969U 86 73  A 90214.31016340  .00000447  00000-0  21224-3 0  4566
2 16969  98.5959 241.2203 0014303 132.9171 227.3210 14.23676806201178
MET-2/16
1 18312U 87 68  A 90220.03064100  .00000220  00000-0  18868-3 0  4736
2 18312  82.5464 249.1868 0012970 101.3486 258.9105 13.83667172150152
MET-2/17
1 18820U 88  5  A 90219.94673158  .00000165  00000-0  13818-3 0  3398
2 18820  82.5471 309.3162 0016720 174.3776 185.7576 13.84359121127346
MET-3/2
1 19336U 88 64  A 90220.00613043  .00000391  00000-0  99999-3 0  5490
2 19336  82.5381 240.7589 0016974 178.4336 181.6839 13.16901083 97773
NOAA-11
1 19531U 88 89  A 90219.90853961  .00000562  00000-0  32972-3 0  3357
2 19531  98.9845 168.2808 0013044 135.9096 224.3118 14.11664674 96266
MET-2/18
1 19851U 89 18  A 90219.93196139 -.00000122  00000-0 -11520-3 0  2837
2 19851  82.5224 187.2304 0013257 215.1407 144.8908 13.83989655 72721
MET-3/3
1 20305U 89 86  A 90219.99870037  .00000300  00000-0  77524-3 0  1921
2 20305  82.5546 181.4555 0015219 194.9740 165.0917 13.15866272 37766
MET-2/19
1 20670U 90 57  A 90220.06575887  .00000078  00000-0  65326-4 0   368
2 20670  82.5439 247.4871 0016819 137.3325 222.9151 13.83842715  5694
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weekend of October 19, 20 and 21, the Confederate Air Force (CAF) has added to the attractions offered by that great Texas city. The CAF has scheduled its big fall flying show and aircraft exhibition of World War ll vintage planes at Ellington Air Force Base, only a few miles from JSC, for October 20 and 21. This year's presentation, called Wings Over Texas, is certain to be outstanding as all CAF shows are.

Eastern Airlines is the Official Airline for the 1990 AMSAT Symposium. A 5% discount price off lowest coach fair or 50% off full first class fair is available. Please give the following ID number to your travel agent or Eastern Airlines: EZ10BP17.

AMSAT-NA
ANNUAL MEETING AND SPACE SYMPOSIUM AGENDA

Friday King's Inn

3:00 - 3:50 PM	Jeff Wallach, N5ITU	Satellite Image Processing for the Amateur
4:00 - 4:50 PM	Rich Ensign, N8IWJ	AMSAT-NA Education Activities: Accomplishments, Possibilities and Prospects
5:00 - 5:50 PM	Dick Campbell, N3FKV	AMSAT Orbital Data Management

Saturday

7:00 - 7:45 AM	King's Inn	CSDP Breakfast

Saturday (day) Johnson Space Center Visitors' Center Auditorium

8:00 - 8:10 AM	Chuck Biggs, KC5RG	Welcome and Announcements
8:10 - 8:35 AM	Gould Smith, WA4SXM	Decoding Telemetry from the Amateur Satellites
8:40 - 9:15 AM	Jan King, W3GEY	In-Orbit Performance of 4 Microsat Spacecraft
9:20 - 9:40 AM	Tom Clark, W3IWI	AO-13 Orbit
9:40 - 10:00 AM	Break	
10:00 - 10:40 AM	Karl Meinzer, DJ4ZC	Report on the Phase 3D Project
10:40 - 10:55 AM	Dick Jansson, WD4FAB & Doug Loughmiller, KO5I	Phase 4 Technology as it Applies to Phase 3D
10:55 - 11:15 AM	Doug Loughmiller, KO5I	OSCAR 14, 9600 Baud Operation
11:20 - 11:40 AM	Courtney Duncan, N5BF	PACSAT Demonstration
11:40 - 12:15 PM	John Champa, K8OCL	Television via Amateur Satellites
12:15 - 1:00 PM	Lunch	
1:00 - 1:35 PM	Jim White, WDØE	Microsat Motion, Stabilization, and Telemetry (and Why We Care About it)
1:40 - 2:15 PM	Lou McFadin, W5DID	SAREX Hardware for STS-35 and 37
2:20 - 2:55 PM	Ron Parise, WA4SIR	STS-35 SAREX Flight Results
3:00 - 3:25 PM	Bill Clapp, KB7KCM	Astronaut Deployable Satellites
3:25 - 3:45 PM	Break	
3:45 - 4:10 PM	Steve Jackson, WD8QCN	WEBERSAT Operations and Experiment Results
4:15 - 4:40 PM	Courtney Duncan, N5BF	AMSAT-NA Operations Organization
4:45 - 5:30 PM	Bob McGwier, N4HY	The Development of 2 DSP Modems

Saturday (evening) JSC Employee's Recreation Center

6:30 - 7:15 PM Attitude Adjustment
7:15 - 9:00 PM Texas Bar-B-Que Dinner
Honored Guest Speaker Mr. Aaron Cohen
Director Johnson Space Center
9:00 - 11:00 PM AMSAT-NA Annual Meeting
Presidents's Report
Current Status of AMSAT-NA
Future Plans
Status Reports on Various Related Amateur Space Programs
SEDSAT (Champa)
Solar Sail (Champa)
DOVE (McGwier)
Award Presentations
Prize Drawings

Sunday King's Inn

7:30 - 8:45 AM	Field Operations Breakfast	
9:00 - 9:55 AM	Keith Pugh, W5IU	Getting Started in Amateur Satellites
10:00 - 10:30 AM	Ed Krome, KA9LNV	Design of an Easy to Build, Versatile, Homebrew Satellite Ground Station
10:30 - 10:55 AM	Alan Fox IV, N5LKJ	Poor Boy Satellite Station
1:00 PM Til	Open house at the world's largest Amateur antenna, W5UN	

Note: A shuttle bus will be available to transport attendees between the King's Inn, the Visitors' Center and the Recreation Center.

AMSAT
850 Sligo Ave. Suite 600
Silver Spring, MD 20910

1990 AMSAT Annual Meeting and Space Symposium

Advance
REGISTRATION FORM

Name________________________

Call__________ AMSAT No.________

Address________________________

City________________________

State_______ Zip_______

Telephone________________________

Advance Registration Fee	*Check*	*Credit Card*
AMSAT Member : $15.00	___	___
Non-member : $20.00	___	___
Saturday Evening Barbecue : $8.00	___	___

Total Remitted (NO CASH)__________

Bill my MC_____ Visa_____

#________________________

Exp. Date_________

Signature________________________

Interested in family activities?
Yes___ No___

XYL/YL_____
Children Number_____ Ages_______

To qualify for Advance Registration, form and remittance must be received by October 10, 1990.

Telemetry: Our Greatest Asset

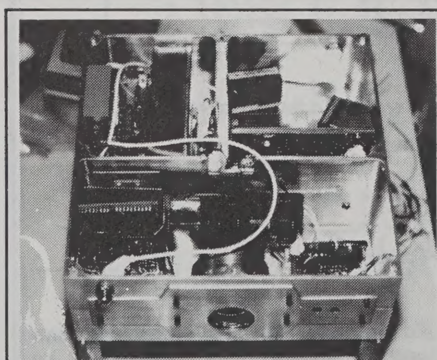
(Continued from page 12)

changes were made to the downlink. As far as the ground stations are concerned, spacecraft passes are short. Real data analysis should be done using larger samples than that obtained at one location so sharing of data is necessary. Ground station software would be GENERIC. The same program should be usable to copy all the current Microsats, the one under construction by AMSAT-Italy, UoSAT-OSCAR 14, Fuji-OSCAR 20 and possibly Phase 3D. The same software would also be usable with Amateur Radio balloon launches and ground or terrestrial telemetry. The generic software would be look-up table driven. Look up tables, stored on a disk, would be used for different spacecraft and experiments and would also take care of preannounced changes in the data from any specific spacecraft.

Summary

A telemetry format standard would lead to user friendly groundstation software becoming available to every educational institution in the world. Such a format would make it easy for software developers to manufacture and market software for use with any of the current and SUSIE type of future satellites. Interest in space will grow by leaps and bounds. NASA may get support from the general public because SUSIE as an ASP or on EOP, could make some of the data from Mission to Planet Earth available to the public in real time as well as for later analysis. Students will be attracted to science and engineering once more as well as Amateur Radio in general and AMSAT in particular.

How about it, that's the opinion of this writer, what do you think?



WEBERSAT Camera Module (W4PUJ photo)

Microsat Motion and Stabilization

(Continued from page 19)

• What are the effects on the RF links of the nutation? Can predictions be correlated to measured signal strength and polarization changes? What are the radiation patterns of the antennas (70 cm downlink, 2 meter downlink, and 2 meter uplink)? What are the best simple ground station antennas to use when nutation is present and when it is not?

• Exactly how quickly did each Microsat achieve magnetic lock? What was the nature of the motion (tumble) in the first few days? How quickly did PACSAT lock as compared to the others, given that it was spinning in the wrong direction?

• Exactly when did PACSAT turn around, and how much, if any, tumble occurred at that time? After it turned around, what was its spin rate each day until it reached a stable rate? How did the temperatures in PACSAT change as its spin slowed down to zero about February 17th? How hot did the +Y surface get when it faced the sun for long periods?

• What is the DOVE spin rate currently, and how fast did it increase since it came out of tumble? A WOD collection of the array currents is planned using a 2 second sample rate. This should allow accurate determination of the spin rate, and also tell us if DOVE's roll over at the equator is delayed or affected at all by its higher spin rate.

• The conical view angle of the IR sensors in all but WEBER needs to be measured so the IR data can be more precisely correlated with other sensor data. What is a more precise method for relating sun angle to solar array current when the sun angle is low?

• What is the exact current drop from a panel when a thick and a thin 2 meter antenna shadow falls on it? What is the effect of shadowing of the S band antennas on the +Z arrays? Under what circumstances will the shadow of the 70 cm and the 2 m downlink antennas fall on the X or Y panels (with and without various amounts of nutation)? Can this be verified with telemetry?

Contact Information

Experimenters interested in pursuing any of these areas should contact the author or Bruce Rahn, WB9ANQ. Bruce is the coordinator of the Command Station Development Program (CSDP) for AMSAT-NA. Information about how to obtain Microsat telemetry from the TLM data bank can be requested from Reid Bristor, WA4UPD. When requesting information please include an SASE, and for data include a disk, mailer and return postage. Contact addresses:

Reid Bristor, WA4UPD
4535 Deerwood Trail
Melbourne, FL 32935

Jim White, WDØE
6642 S. Dover Way
Littleton, CO 80123

Compuserve: 71477,546

Bruce Rahn, WB9ANQ
410 Colorado Trail
Enon, Ohio 45323

Glossary:

ADC	Analog to Digital Converter
ASAP	Auxiliary Secondary Payload Adaptor
MUX	Multiplexer
OBC	On board Computer
TCA	Time of Closest Approach. The time at which the satellite comes closest to the ground station.
TLM	Telemetry
WOD	Whole Orbit Data. Data collected for one or more entire orbit and downloaded in one package.

References

1. For a photo illustrating the mounting of the Microsats on the ASAP see *AMSAT Journal*, V13 #1, March 90, pp28.

2. For a photo illustrating the black and white painted antenna blades see *AMSAT Journal*, V12 #1, May 89, pp8.

3. Full nomenclature for the stabilization method is "passive magnetic attitude stabilization with photon assisted spin".

4. Microsat Telemetry Equations, *AMSAT Journal*, V13 #1, March 90, pp24-25.

5. WEBERSAT, Stan Sjol, WØKP, *AMSAT Journal*, V12 #3, Nov 89. *A Brief User's Manual for WEBERSAT'S Ancillary Experiments*, Chris Williams, WA3PSD, Center for Aerospace Technology, Weber State University, Ogden, Utah, 84408-1805.

Acknowledgments

Thanks go to Jan King, W3GEY, for generously sharing his vast knowledge, Chris Williams, WA3PSD, for his patience in explaining the WEBER attic, Bob McGwier, N4HY, and Harold Price, NK6K, for their assistance with telemetry formats and WOD collection, Franklin Antonio, N6NKF, for providing the math describing the Earth's magnetic field, and Ron Cox, Stan Woods, Richard, VK7ZBK, and Graham Ratcliff, VK5AGR, for data collection and reporting.